STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

REPORT OF INVESTIGATIONS NO. 51

UPPER NIAGARAN AND CAYUGAN STRATIGRAPHY

OF

NORTHEASTERN OHIO AND ADJACENT AREAS

by

JOHN R. ULTEIG

COLUMBUS
1964

STATE OF OHIO

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$2.00 plus tax

Foreword

This report has been adapted from a thesis submitted by John R. Ulteig to the Department of Geology and the Graduate School of the University of Wyoming in partial fulfillment of requirements for the degree of Master of Science.

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ABSTRACT

This paper presents a regional subsurface stratigraphic study of the upper Niagaran and Cayugan sedimentary rocks of northeastern Ohio and adjacent areas. Data derived from sample descriptions or geophysical logs of 118 wells are employed to construct eight isopach maps, a structure map, and seven cross sections that illustrate the stratigraphic relationships of the various lithologic units present in the subsurface.

The nomenclature presently applied to the Salina Group in the subsurface section of the Michigan basin is practical for subdivision of the group in northeastern Ohio. The formations of the Lockport and Bass Islands Groups described from exposures in western Ohio are not identifiable in the subsurface section.

"Newburg sand", a drillers' term originally designating a porous zone directly below the Niagaran-Cayugan contact, has been applied to any interval within the Lockport Group which is composed of porous, brown, crystalline dolomite with the drilling characteristics of a sandstone. Available subsurface data do not indicate an unconformable contact between the strata of Niagaran and Cayugan age; however, definite evidence of an unconformity in the outcrop sections to the west seems to indicate at least local areas of unconformity in the subsurface.

Subsurface correlations indicate that the Greenfield Formation, as described from outcrops, is stratigraphically equivalent to the A-unit carbonate rocks of the Michigan basin. No salt was observed in samples from the Greenfield Formation. The Tymochtee Formation, as presently defined, is equivalent to the B, C, D, E, F, and G units proposed by Landes in the Michigan basin; however, the type section of the Tymochtee, described by Winchell, is probably equivalent to a part of the subsurface C unit.

The various salt beds present in northeastern Ohio are mappable stratigraphic units which can be correlated with those in Michigan on the basis of lithologic and gamma-ray log characteristics. The rock sequence containing salt in the Ohio evaporite basin can be traced to the outcrop area along the Findlay arch where it is shown to be equivalent to the Tymochtee Formation.

In eastern Ohio and western Pennsylvania, the Silurian-Devonian contact is apparently conformable. Westward from this area, progressively older Silurian rocks are truncated below an unconformity and the subcrop pattern of the various Silurian rock units below Devonian carbonate rocks can be illustrated. In the southwest corner of the project area, the F and G units, and the Bass Islands Group were removed by erosion and Devonian carbonate rocks unconformably overlie the E unit of the Salina Group.

The structural framework of the region during late Niagaran and Cayugan time was oriented in a northwest-southeast direction. The axis of the major depositional basin trended in this direction through Cuyahoga, Portage, Mahoning, and Columbiana Counties. Two minor depositional basins are indicated by the investigation; one during Lockport-Greenfield time in Lorain, Medina, and Ashland Counties and another in Lake and Ashtabula Counties during B-unit time.

INTRODUCTION

PURPOSE AND SCOPE

This investigation of the upper Niagaran and Cayugan stratigraphy of northeastern Ohio and adjacent areas was undertaken in order to supplement a study of the "Big Lime"[1] initiated by Dow (1962), who described the Devonian portion of this stratigraphic interval. The stratigraphic studies of Dow were limited to the subsurface section of northeastern Ohio and adjacent areas. This study is restricted to the same region, which includes all or parts of thirty counties in northeastern Ohio, an area of approximately 10,000 square miles (figs. 1, 2, and 3). It is regional in scope; detailed investigation of limited areas or specific stratigraphic intervals is beyond the purview of the report.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. R. L. Bates of the Department of Geology, Ohio State University, who, acting for Dr. H. D. Thomas, thesis advisor, University of Wyoming, gave freely of his time to supervise the preparation of the thesis from which this report was derived; and to Mr. R. J. Bernhagen, Mr. W. L. Calvert and other members of the Ohio Division of Geological Survey, who made available all necessary information for the completion and publication of this study.

The writer also wishes to thank the many people in the Appalachian-Michigan basin area who offered information, comments, and criticism during preparation of this paper. Special thanks are due the Skelly Oil Company and the Department of Geology of the University of Wyoming for permitting the release of this manuscript. The writer is also grateful to the personnel of the Skelly Oil Company for aiding in the reproduction of illustrations, and for constructive criticism during the course of the investigations.

METHODS OF INVESTIGATION

Except for scattered exposures along the west side of the project area, the stratigraphic units considered in this study are overlain by younger sediments. The data utilized to complete this report were obtained from wells which penetrate the strata of upper Niagaran and Cayugan age. Subsurface information, available from three basic sources: drillers' logs, geophysical logs, and well cuttings, was obtained from the Ohio Division of Geological Survey.

Control data are abundant within the part of the area that produces gas and oil from the "Clinton" sands of Medina age, but geophysical logs are not available for wells in the western part of the area of investigation (fig. 1). For western Ohio the writer had to use sample descriptions without the aid of geophysical logs in completing this study.

1. "Big Lime" is a drillers' term for the carbonate-evaporite sequence between the underlying Clinton or "Niagaran" shale and the overlying Devonian shales. It includes limestone of Lower and Middle Devonian age as well as Silurian carbonate and evaporite rocks.

Some basic information was obtained from drillers' logs; however, geophysical logs and sample descriptions by the writer were the major sources of data. The locations of the 118 wells from which data were obtained are shown in figure 1, and these wells are identified in table 1. A well represented on a cross section is identified by a number with a letter prefix designating the cross section on which the well appears; the numbers are consecutive from left to right across the section. A well not represented on a cross section is identified by number only.

Well samples were studied with the aid of a ten-power binocular microscope. Color of the sample fragments was determined by comparison with the colors of the G. S. A. Rock-Color Chart. Clastic grain size and carbonate crystal size were measured by sand scale obtained from the Geological Specialty Company.

Sample cuttings from 30 wells were studied. Graphic lithologic columns for 24 of these wells are presented on the cross sections, and sample descriptions of six of these wells (A3, B4, B7, B12, C1, and C9), which are representative of various parts of the area of this investigation, are included in appendix B.

The geophysical logs available for study are of four basic types: gamma-ray, neutron, resistivity, and sonic. The majority of the logs consist of a gamma-ray log in combination with one of the other three types.

The lithology and rock units indicated by the sample descriptions were integrated to the geophysical log characteristics in fifteen wells (shown on figure 1 by solid circles) for which both a geophysical log and a set of sample cuttings were available. These control wells were utilized to correlate the other geophysical logs in adjoining parts of the thesis area. The depth of the various rock units below the surface, determined for the wells listed on table 1, is tabulated in appendix A.

From the data listed in appendix A, seven cross sections, eight isopach maps, and a structure map were constructed to illustrate correlation and thickness variations of the rock units within the sedimentary section studied. The cross sections were constructed from data obtained from 41 wells throughout the area. The top of the "Big Lime" is used as a reference datum in constructing the cross sections, because it is a prominent, easily recognized horizon in the Ohio section that is recorded on most well records. The locations of the cross sections, A-A' through G-G', are shown on figure 1; and these sections are illustrated on Plates 2 through 8.

The isopach maps and Clinton shale structure map, constructed from the appropriate data in appendix A, are shown on figures 4, 5, 7, 8, 9, 10, 11, 12, and 13. These maps are discussed in the stratigraphy section.

GENERAL GEOLOGY

The major structural features in the region of the area under investigation are the Michigan, Appalachian, and Illinois basins; these are separated by an arch system consisting of the Cincinnati, Findlay, Kankakee, and Algonquin arches. The project area is situated on the northwest flank of the Appalachian basin, directly east of the Findlay arch (fig. 2).

The sedimentary section in the Appalachian-Michigan basin region consists of rocks ranging in age from Cambrian to Permian. Quaternary glacial sediments, having a thickness of as much as 300 feet, cover some parts of the region. Total thickness of sedimentary strata ranges from a featheredge along the areas of igneous rock outcrops to more than 20,000 feet in the interior of the Appalachian basin (fig. 2).

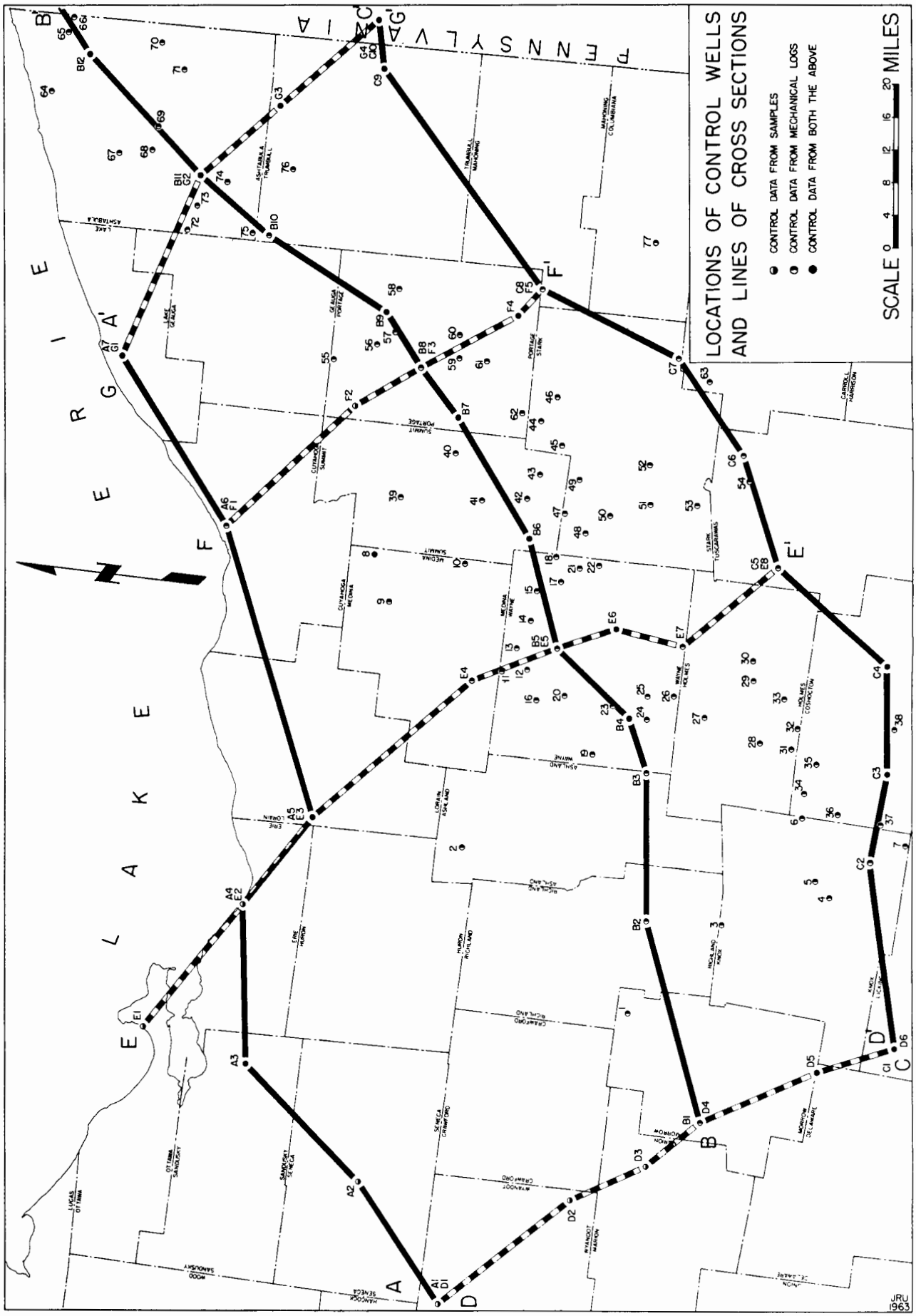
LOCATIONS OF CONTROL WELLS
AND LINES OF CROSS SECTIONS
CONTROL DATA FROM SAMPLES
CONTROL DATA FROM MECHANICAL LOGS
CONTROL DATA FROM BOTH THE ABOVE
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU 1963

Figure 1

Table 1. - LIST OF CONTROL WELLS USED IN THIS STUDY
(Locations of wells are shown on figure 1. For explanation of well numbers refer to page 3.)

Well Number	County	Township	Sec. or Lot	Operator	Farm	State Permit No.	Sample No.
A1 (D1)	Wyandot	Crawford	18	Ohio Oil	Heck	72	99
A2	Seneca	Clinton	17	Sun	UAM	20	747
A3	Sandusky	Townsend	33	East Ohio Gas	Haff	77	895
A4 (E2)	Erie	Huron	City	Nickel Plate	NYCRR	5	695
A5 (E3)	Lorain	Henrietta	L8	East Ohio Gas	Born	794	894
A6 (F1)	Cuyahoga	Cleveland	City	Sohio	Sohio	--	--
A7 (G1)	Lake	Painesville	L49	Diamond Alkali	Diamond Alkali	204	33
B1 (D4)	Morrow	Cardington	9	Cassidy	Barton	23	--
B2	Richland	Washington	24	Gant	Channell	223	--
B3	Ashland	Lake	2	Stewart	Mosher	1762	--
B4	Wayne	Plain	25	Kubat	Sanger	1169	914
B5 (E5)	Wayne	Green	6	Wehmeyer	Hohenshil	979	--
B6	Summit	Franklin	17	East Ohio Gas	Kiminecz	311	742
B7	Portage	Brimfield	L22	East Ohio Gas	Heichel	40	721
B8 (F3)	Portage	Ravenna	L8	Hinton	Hinman	56	--
B9	Portage	Freedom	L42	N. Natural Gas	Wilson	85	928
B10	Trumbull	Mesopotamia	L48	N. Natural Gas	Wengerd	16	--
B11 (G2)	Ashtabula	Rome	L25	Wehmeyer	Kellogg	86	834
B12	Ashtabula	Monroe	L1	McConnell	Brydle	73	818
B13	Erie (Pa.)	Girard	--	Worldwide	Barney	--	--
B14	Erie (Pa.)	Summit	--	Stephens	Goodwill-Curley	62	--
C1 (D6)	Licking	Hartford	L2	Patten	Martin	1803	855
C2	Knox	Jackson	5	Alkire & Floto	Earlywine	1265	--
C3	Coshocton	Bedford	7	Natol	Gilmore	1203	761
C4	Coshocton	Keene	L15	Roberson etal	Geib	880	694
C5 (E8)	Tuscarawas	Sugar Creek	21	Nat. Assoc. Pet.	Borntrager	794	--
C6	Tuscarawas	Sandy	L10	Status Devel.	Sattler	676	--
C7	Stark	Paris	32	Nat. Gas W. V.	Czekomski	963	--
C8 (F5)	Mahoning	Smith	4	Atlas	Miller	121	--
C9	Trumbull	Hartford	L25	Dinger	Blaney	12	816
C10 (G4)	Mercer (Pa.)	Pymatuning	--	Melben	McKnight	6	--
D1 (A1)	Wyandot	Crawford	18	Ohio Oil	Heck	72	99
D2	Wyandot	Antrim	28	Ohio Oil	Chatlain	--	4
D3	Marion	Claridon	9	White	Baker	3	627
D4 (B1)	Morrow	Cardington	9	Cassidy	Barton	23	--
D5	Delaware	Porter	L16	Monk	Thurston	2	--
D6 (C1)	Licking	Hartford	L2	Patten	Martin	1803	855
E1	Ottawa	Catawba	--	Hilliard	Wiechel	20	711
E2 (A4)	Erie	Huron	City	Nickle Plate Devel.	NY, C, StL RR	5	695
E3 (A5)	Lorain	Henrietta	L8	East Ohio Gas	Born	794	894
E4	Medina	Westfield	L10	King	Hawley	72	--
E5 (B5)	Wayne	Green	6	Wehmeyer	Hohenshil	979	--
E6	Wayne	East Union	10	Heyser	Yoder	833	791
E7	Wayne	Salt Creek	21	Ohio Fuel Gas	Petersheim	1229	--
E8 (C5)	Tuscarawas	Sugar Creek	21	Nat. Assoc. Pet.	Borntrager	794	--
F1 (A6)	Cuyahoga	Cleveland	City	Sohio	Sohio	--	--
F2	Portage	Aurora	L19	McIntyre	Tacl	51	805
F3 (B8)	Portage	Ravenna	L8	Hinton	Hinman	56	--
F4	Portage	Atwater	L16	Atlas	Franks	77	912
F5 (C8)	Mahoning	Smith	4	Atlas	Miller	121	--
G1 (A7)	Lake	Painesville	L49	Diamond Alkali	Diamond Alkali	204	33
G2 (B11)	Ashtabula	Rome	L25	Wehmeyer	Kellogg	86	834
G3	Trumbull	Gustavus	L77	N. Nat. Gas	Runkle	15	897
G4 (C10)	Mercer (Pa.)	Pymatuning	--	Melben	McKnight	5	--
1	Morrow	Troy	18	Pan American	Windbigler	47	--
2	Ashland	Ruggles	L14	Dalton Hanna	Eshtruth	1784	--
3	Knox	Pike	6	Ringler	Drushawl	1418	--
4	Knox	Harrison	L26	Mammoth	White	1251	--
5	Knox	Howard	L2	Alkire & Floto	Welker	1265	--
6	Knox	Union	L3	Collins	Simmons	1039	--
7	Knox	Jackson	22	Blood	Miller	800	--
8	Medina	Hinckley	L52	Wiser	Divoky	1256	844

Table 1. - LIST OF CONTROL WELLS USED IN THIS STUDY (con.)
(Locations of wells are shown on figure 1. For explanation of well numbers refer to page 3.)

Well Number	County	Township	Sec. or Lot	Operator	Farm	State Permit No.	Sample No.
9	Medina	Medina	L2	Ohio Fuel Gas	Deiss	1296	--
10	Medina	Sharon	L69	Natol	Shanafelt	1014	--
11	Wayne	Canaan	3	King	Smith	1098	--
12	Wayne	Canaan	22	Wehmeyer	Fetzer	966	--
13	Wayne	Milton	7	Parker Chapman	Rufever	1133	--
14	Wayne	Milton	22	Storey	McConnell	945	--
15	Wayne	Chippewa	20	East Ohio Gas	Steiner	822	--
16	Wayne	Canaan	30	Slagter	Armstrong	460	--
17	Wayne	Baughman	4	East Ohio Gas	Brillhart	925	--
18	Wayne	Chippewa	36	East Ohio Gas	Magyar	498	--
19	Wayne	Plain	6	Acitelli Hackel	Guenther	834	--
20	Wayne	Wayne	17	Vanson	Boreman	894	--
21	Wayne	Baughman	14	East Ohio Gas	Shisler	900	--
22	Wayne	Baughman	25	Ohio Fuel Gas	Eberly	1188	--
23	Wayne	Wooster	18	Phillips	Stockdale	790	--
24	Wayne	Clinton	1	Arrowhead	Johnson	987	--
25	Wayne	Franklin	33	Natol	Grosjean	1148	--
26	Wayne	Franklin	21	Vanson	Lloyd	795	--
27	Holmes	Prairie	7	Fields	McCurdy	1055	--
28	Holmes	Killbuck	3	Natol	Zangg	1143	--
29	Holmes	Hardy	20	Parker Chapman	Reining	1094	--
30	Holmes	Berlin	L10	Arrowhead	Hockstetler	1115	--
31	Holmes	Killbuck	23	Hinton	Snow	932	--
32	Holmes	Killbuck	25	Nepple	Snow	1064	--
33	Holmes	Mechanic	10	Davis	Weitbrecht	995	--
34	Coshocton	Tiverton	8	Bears	Day	1379	--
35	Coshocton	Monroe	L23	Natol	Hawkins	1439	--
36	Coshocton	Newcastle	L8	Rixleben	Conservancy	1449	--
37	Coshocton	Perry	6	Bears	Rine	1002	--
38	Coshocton	Jackson	7	Arrowhead	Foster	1269	--
39	Summit	Northampton	L71	East Ohio Gas	Wheatley	17	--
40	Summit	Tallmadge	L6	Brannon	Streitenberger	377	--
41	Summit	Coventry	L10	Diamond Crystal	Diamond Crystal	366	--
42	Summit	Green	7	East Ohio Gas	Costello	D10	--
43	Summit	Green	15	East Ohio Gas	Groves	348	--
44	Stark	Lake	10	Atlas	Bledsoe	1038	--
45	Stark	Lake	28	East Ohio Gas	Coblenta	1002	--
46	Stark	Marlboro	19	Natol	Hall	967	--
47	Stark	Lawrence	1	East Ohio Gas	Rohr 3	D7	--
48	Stark	Lawrence	22	East Ohio Gas	Tippel	1020	--
49	Stark	Jackson	10	East Ohio Gas	Hixon	D3	--
50	Stark	Lawrence	36	East Ohio Gas	Neisel	1056	--
51	Stark	Perry	29	East Ohio Gas	Dielhenn	1021	--
52	Stark	Canton	19	Ashland	Ashland	--	--
53	Stark	Bethlehem	21	Nat. Gas W. V.	Stansberger	949	--
54	Tuscarawas	Lawrence	L112	Status Devel.	Wassem	671	--
55	Portage	Mantua	L3	N. Nat. Gas	Frost	73	--
56	Portage	Shalersville	L30	N. Nat. Gas	Goodell	70	--
57	Portage	Freedom	L79	N. Nat. Gas	Moore	68	--
58	Portage	Windham	L53	N. Nat. Gas	Showalter	76	--
59	Portage	Rootstown	L17	Fields	Arnette	55	--
60	Portage	Edinburg	L12	East Ohio Gas	McConnell	86	--
61	Portage	Rootstown	L13	East Ohio Gas	Smith	71	--
62	Portage	Suffield	L20	Atlas	Schweikert	63	--
63	Carroll	Brown	24	Humble	Davies	212	--
64	Ashtabula	Kingsville	L32	Atlas	County	27	--
65	Ashtabula	Conneaut	L31	East Ohio Gas	Collet	148	--
66	Ashtabula	Monroe	L24	Britton	Frigic	90	--
67	Ashtabula	Austinburg	L48	N. Nat. Gas	Judson	91	--
68	Ashtabula	Morgan	L40	Mouser etal	Jamison	88	--
69	Ashtabula	Lenox	L15	N. Nat. Gas	Harmon	96	--
70	Ashtabula	Richmond	L16	N. Nat. Gas	Romanowski	98	--
71	Ashtabula	Dorset	L2	Benedum	Power	113	--
72	Ashtabula	Hartsgrove	L31	Mouser etal	Roach	82	--
73	Ashtabula	Hartsgrove	L67	N. Nat. Gas	Musial	99	--
74	Ashtabula	Orwell	L2	N. Nat. Gas	Haznos	131	--
75	Ashtabula	Windsor	L1	N. Nat. Gas	Clark	103	--
76	Trumbull	Bloomfield	L148	N. Nat. Gas	Frandrich	13	--
77	Columbiana	Hanover	10	Atlas	Batzli	539	--

The upper Niagaran and Cayugan section crops out around the margins of the various basins, as shown on fig. 3. The sedimentary rocks of this age are truncated around the basin margins and are more than 4,000 feet thick in the basin interiors.

The regional dip in northeastern Ohio is approximately 35 feet per mile in a southeasterly direction. A structure map (fig. 4) contoured on the base of the Lockport Group illustrates the present structural relationship. Within the project area the total sedimentary section, Cambrian to Pennsylvanian in age, ranges in thickness from 2,000 feet in the west to 10,000 feet in the east. The thickness of the upper Niagaran and Cayugan portion of the rock column ranges from less than 200 feet in the west, where the Lockport is exposed at the surface, to approximately 1,700 feet in Columbiana County, where the Cayugan strata lie 5,000 feet below the surface. Figure 5, a "Big Lime" isopach map, illustrates the thickening of the section within the area of this study.

NOMENCLATURE

DEVELOPMENT OF UPPER NIAGARAN AND CAYUGAN NOMENCLATURE

The development of nomenclature is presented here under two subheadings, outcrop and subsurface, for several reasons. The sedimentary rocks deposited on the margin of an evaporite basin (outcrop area) are distinctly different from the sedimentary rocks deposited within the interior of the basin. Secondly, many formations or members recognizable at surface exposures are not recognizable in the subsurface from well samples or geophysical logs. Finally, the subsurface nomenclature of the Salina Group was developed independently of the outcrop nomenclature, and both systems are used in various areas at the present time.

Outcrop Nomenclature

The early reports of the New York Geological Survey contain the first published accounts of the rocks of Silurian age in the United States. During the late 1830's, T. A. Conrad, J. Hall, and L. Vanuxem initiated the present Silurian nomenclature by proposing terms for the sedimentary section exposed in the state of New York.

The "Onondaga limestone series", a term proposed by Conrad in 1837, was subdivided by Hall two years later into the Lockport Group and the Onondaga Salliferous Group in ascending order. Vanuxem, in 1840, proposed the name "Onondaga Salt Group" for the formations that contained salt. The term "Onondaga" was limited by Emmons in 1846 to limestones of Devonian age.

Hall proposed the term "Niagara Group" in 1842. This group consisted of the Rochester Shale overlain by the Lockport Limestone. Ten years later, the term "Guelph or Gault Formation" was introduced by Hall for a formation exposed in Ontario, between the top of the Lockport and the base of the Onondaga Salt Group. He included this formation at the base of the Onondaga Salt Group, although the fossil content was distinct. In 1863, the term "Salina period" was introduced by Dana. This period included the epochs of deposition of the Guelph Limestone and the Onondaga Salt Group. During the following years, the Guelph Formation was placed in the Niagaran Group, but controversy still exists as to its faunal correlation.

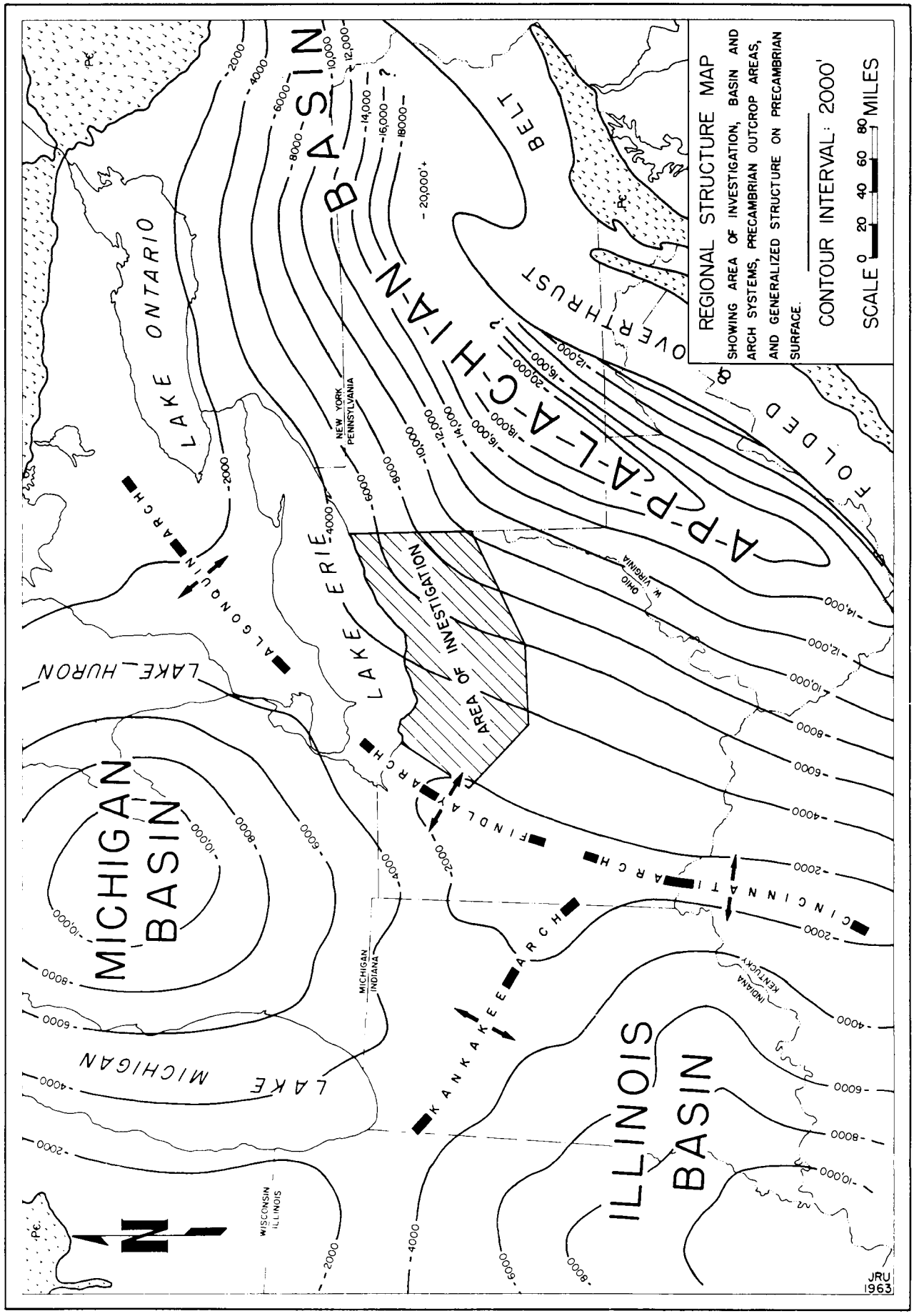
REGIONAL STRUCTURE MAP
SHOWING AREA OF INVESTIGATION, BASIN AND ARCH SYSTEMS, PRECAMBRIAN OUTCROP AREAS, AND GENERALIZED STRUCTURE ON PRECAMBRIAN SURFACE.
CONTOUR INTERVAL: 2000'
SCALE 0 20 40 60 80 MILES
A-P-P-A-L-A-C-H-I-A-N B-A-S-I-N
OVERTHRUST BELT
TOLEDO
LAKE ONTARIO
LAKE ERIE
LAKE HURON
LAKE MICHIGAN
MICHIGAN BASIN
ILLINOIS BASIN
AREA OF INVESTIGATION
ALGONQUIN ARCH
FINDLAY ARCH
CINCINNATI ARCH
KANKAKEE ARCH
NEW YORK
PENNSYLVANIA
OHIO
W. VIRGINIA
MICHIGAN
INDIANA
INDIANA
KENTUCKY
WISCONSIN
ILLINOIS
JRU
1963

Figure 2

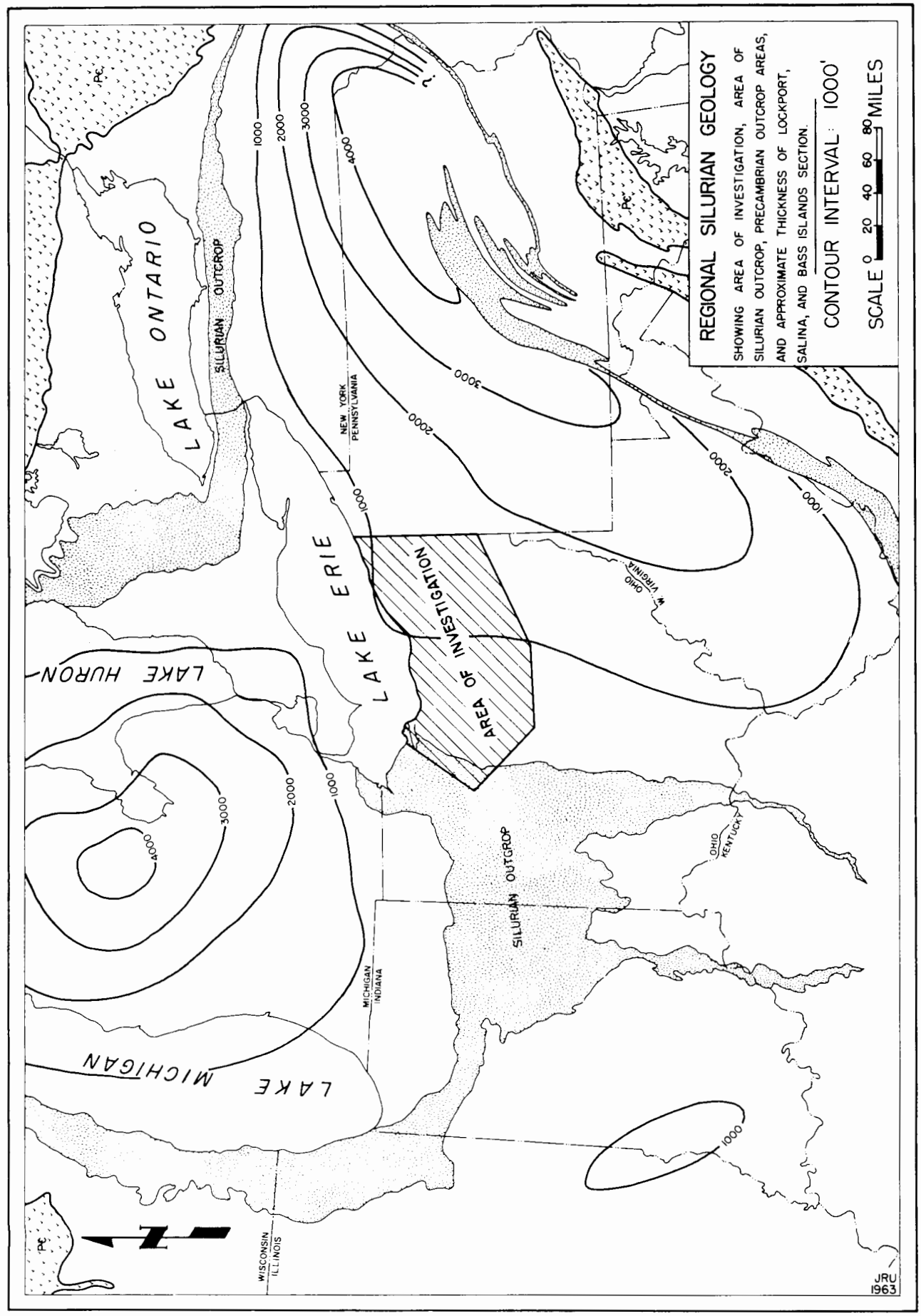
REGIONAL SILURIAN GEOLOGY
SHOWING AREA OF INVESTIGATION, AREA OF SILURIAN OUTCROP, PRECAMBRIAN OUTCROP AREAS, AND APPROXIMATE THICKNESS OF LOCKPORT, SALINA, AND BASS ISLANDS SECTION.
CONTOUR INTERVAL 1000'
SCALE 0 20 40 60 80 MILES
LAKE ONTARIO
LAKE ERIE
LAKE HURON
LAKE MICHIGAN
SILURIAN OUTCROP
AREA OF INVESTIGATION
NEW YORK
PENNSYLVANIA
OHIO
W. VIRGINIA
OHIO
KENTUCKY
MICHIGAN
INDIANA
WISCONSIN
ILLINOIS
Pc
1000
2000
3000
4000
JRU
1963

Figure 3

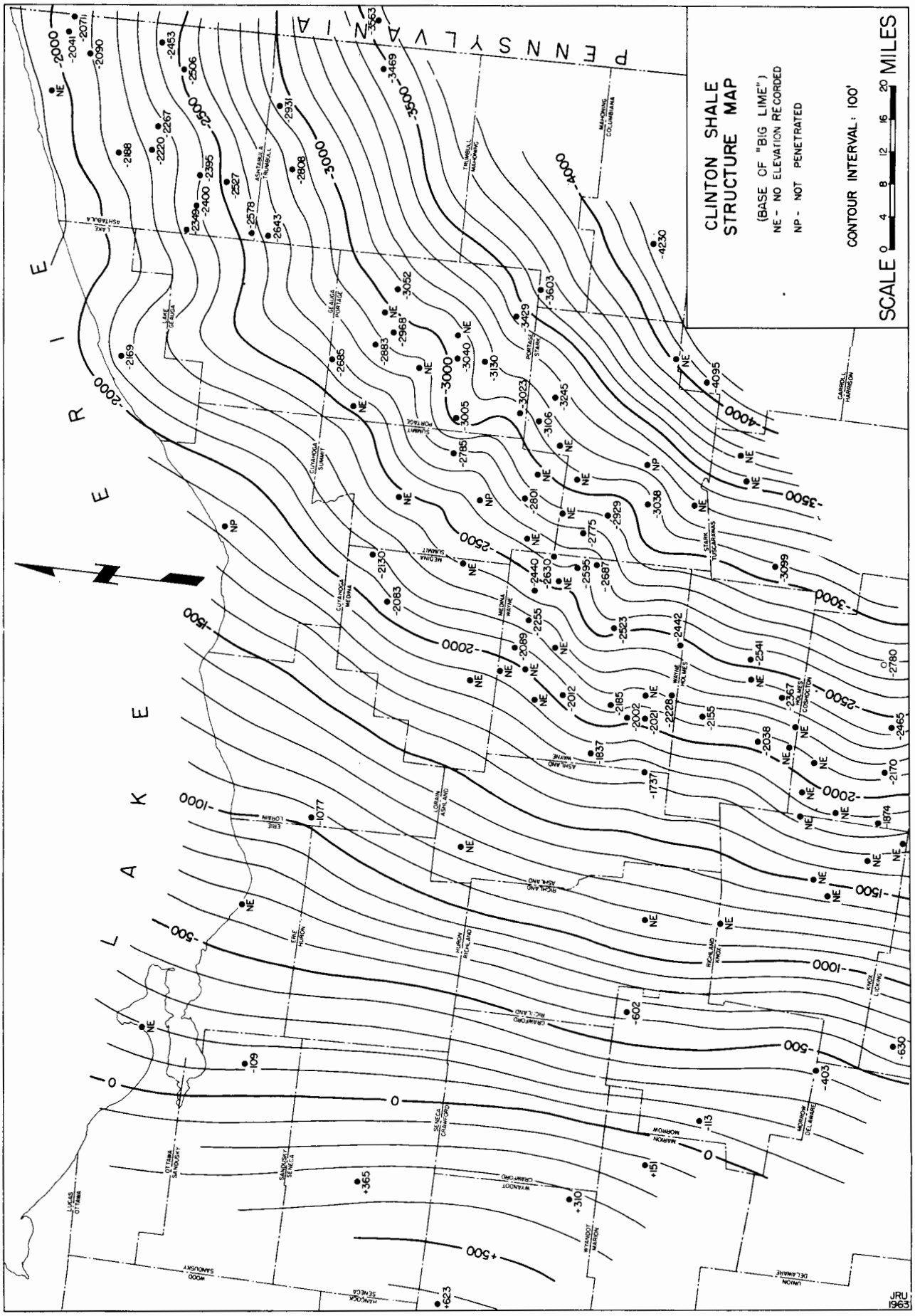
CLINTON SHALE
STRUCTURE MAP
(BASE OF "BIG LIME")
NE - NO ELEVATION RECORDED
NP - NOT PENETRATED
CONTOUR INTERVAL: 100'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
ERIE
LAKE
JRU
1963

Figure 4

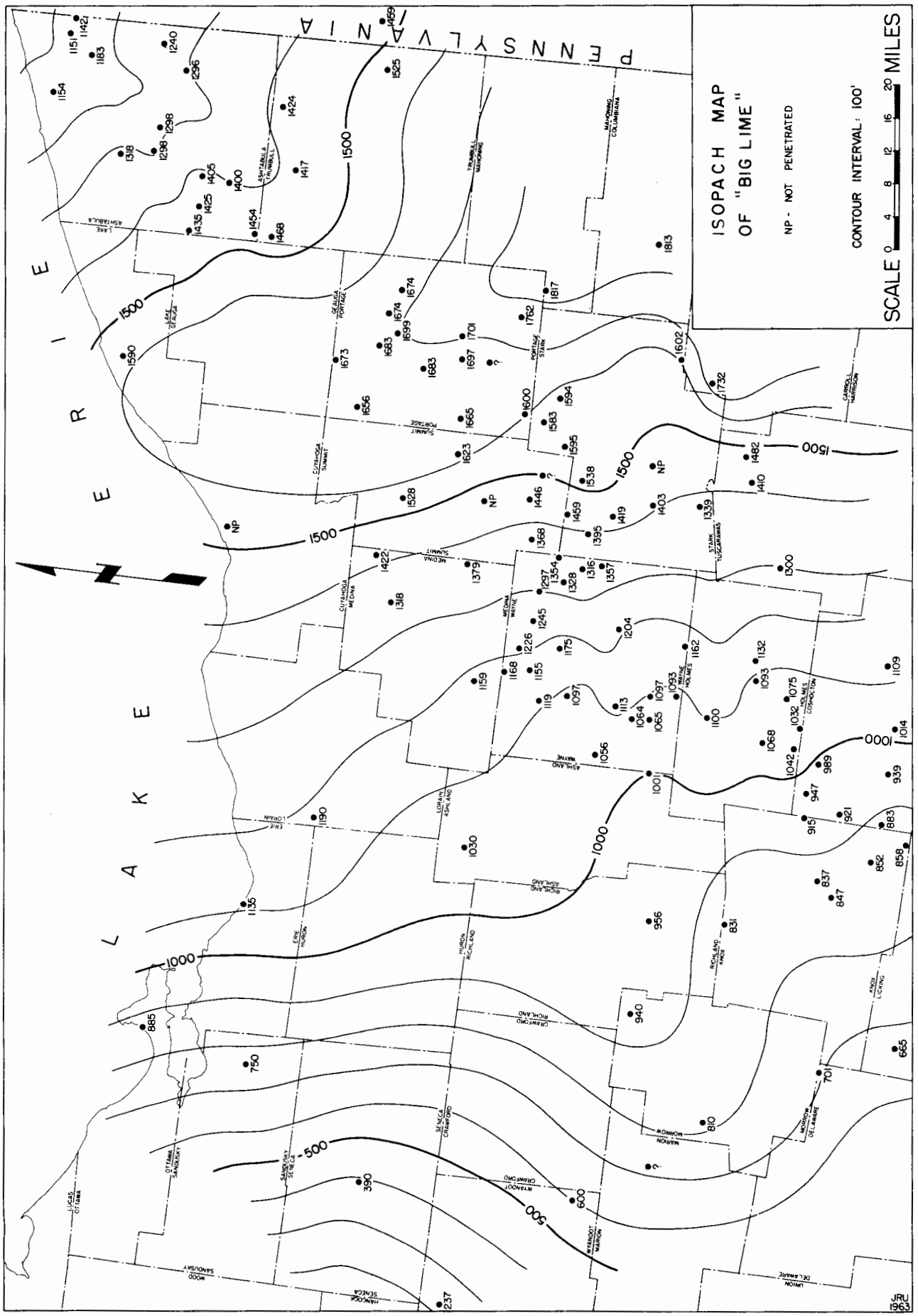
ISOPACH MAP
OF "BIG LIME"
NP - NOT PENETRATED
CONTOUR INTERVAL: 100'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU
1963

Figure 5

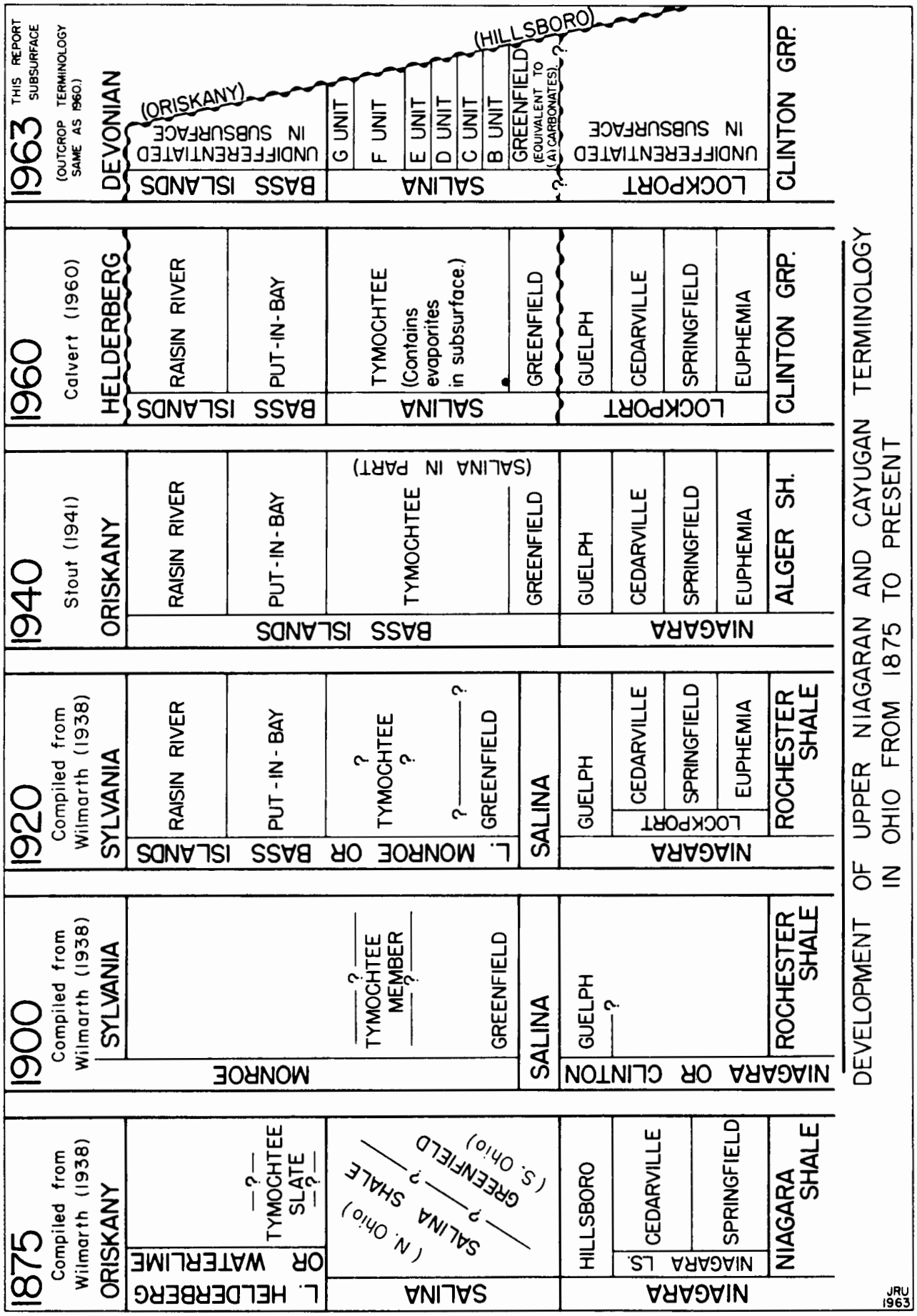
1875
Compiled from Wilmarth (1938)
ORISKANY
L. HELDERBERG OR WATERLIME
TYMOCHTEE SLATE
SALINA
(N. Ohio) SALINA SHALE ? ? GREENFIELD (S. Ohio)
NIAGARA
HILLSBORO
NIAGARA L.S.
CEDARVILLE
SPRINGFIELD
NIAGARA SHALE
1900
Compiled from Wilmarth (1938)
SYLVANIA
MONROE
TYMOCHTEE MEMBER
GREENFIELD
SALINA
NIAGARA OR CLINTON
GUELPH
ROCHESTER SHALE
1920
Compiled from Wilmarth (1938)
SYLVANIA
RAISIN RIVER
PUT-IN-BAY
BASS ISLANDS OR L. MONROE
TYMOCHTEE
GREENFIELD
SALINA
NIAGARA
GUELPH
LOCKPORT
CEDARVILLE
SPRINGFIELD
EUPHEMIA
ROCHESTER SHALE
1940
Stout (1941)
ORISKANY
RAISIN RIVER
PUT-IN-BAY
BASS ISLANDS
(SALINA IN PART)
TYMOCHTEE
GREENFIELD
NIAGARA
GUELPH
CEDARVILLE
SPRINGFIELD
EUPHEMIA
ALGER SH.
1960
Calvert (1960)
HELDERBERG
RAISIN RIVER
PUT-IN-BAY
BASS ISLANDS
TYMOCHTEE (Contains evaporites in subsurface.)
GREENFIELD
SALINA
GUELPH
CEDARVILLE
SPRINGFIELD
EUPHEMIA
LOCKPORT
CLINTON GRP.
1963
THIS REPORT SUBSURFACE
(OUTCROP TERMINOLOGY SAME AS 1960.)
DEVONIAN
(ORISKANY)
(HILLSBORO)
UNDIFFERENTIATED IN SUBSURFACE
BASS ISLANDS
G UNIT
F UNIT
E UNIT
D UNIT
C UNIT
B UNIT
GREENFIELD (EQUIVALENT TO (A) CARBONATES)
SALINA
UNDIFFERENTIATED IN SUBSURFACE
LOCKPORT
CLINTON GRP.
DEVELOPMENT OF UPPER NIAGARAN AND CAYUGAN TERMINOLOGY IN OHIO FROM 1875 TO PRESENT
JRU 1963

Figure 6

Development of nomenclature of the Silurian outcrop area of western Ohio began during the late 1860's. The various changes from 1875 to 1960 are shown on figure 6. Edward Orton (1871) proposed the terms "Springfield Limestone" and "Cedarville Dolomite" of Niagaran age, and "Greenfield Dolomite" of Salina age, for exposures in southwestern Ohio. In 1917, Foerste described a section of dolomite exposed in a quarry near Euphemia, Preble County, Ohio, and named the formation after that village. The term "Tymochtee Slate" was proposed by Winchell in 1873 for an exposure of dolomitic shale in Wyandot County. The upper and lower limits of the unit were not exposed, but Winchell placed this section within the "waterlime".[2]

In 1893, reported by M. E. Wadsworth, A. C. Lane proposed the name "Monroe Group" for the section overlying the Niagaran Group to the base of the Dundee Limestone of Devonian age. The Monroe was later divided into upper and lower units, separated by the Sylvania Sandstone. Lane, Prosser, Sherzer, and Grabau in 1909 replaced the name Lower Monroe with Bass Islands and divided the group into four formations. In ascending order, they are Greenfield, Tymochtee, Put-in-Bay, and Raisin River.

Subsurface Nomenclature

Until recent years, the subdivision of the upper Niagaran and Cayugan subsurface section in northeastern Ohio was based, for the most part, on drillers' terms. Drillers reported major lithologic breaks, recognizable by changes in drilling conditions, and zones of porosity. "Newburg", "Second Water", and "Big Water" are drillers' terms designating porous zones in the lower part of the "Big Lime".

During the course of their operations in Ohio, the salt companies have developed a method of designating the various salt horizons, numbering them from one to four in descending order. This system was developed to facilitate communication about the various salt beds, and was not intended for use outside the area of salt production in Cuyahoga and Lake Counties.

In recent years, the formal group names, Lockport, Salina, and Bass Islands, have been used in the subsurface. The group names, drillers' terms, and numbered salt layers, although not interrelated, are the basis of upper Niagaran and Cayugan subsurface nomenclature in Ohio at present.

For the past several years, the Lockport Group has been divided in the Michigan basin on the basis of color, and the intervals designated by the drillers' terms "White Niagaran", "Grey Niagaran", and "Brown Niagaran" in ascending order. Recently, Alguire (1962) and Pounder (1962), while studying the stratigraphy of the Niagaran rocks, have devised methods of subdividing the Lockport in the subsurface on the basis of gamma-ray logs and sample studies. Each has proposed three stratigraphic intervals within the Lockport. Alguire, working in Michigan, designates the intervals equivalent to the drillers' terms as Zones 1 through 3 in ascending order; and Pounder, studying the Lockport of Ontario, refers to the intervals as Units I through III in descending order. The two systems utilize similar lithology and geophysical log characteristics to subdivide the Lockport.

After studying well samples from the Michigan basin area, Landes (1945) proposed that the Salina Group is divisible on the basis of lithologic differences; primarily, on the existence of extensive and continuous layers of salt. Landes divided the Salina

2. The term "waterlime" occurs often in the literature of both New York and Ohio from 1840 to 1880, and usually refers to the carbonate rocks lying between the Salina Group and the Oriskany Sandstone.

of the Michigan basin into informal units which he lettered A through H in ascending order. As Alling and Briggs (1961) state: "The study by Landes (1945) of the subsurface rocks in the Michigan basin pioneered the regional analysis of evaporites and provided an entirely new standard of stratigraphic nomenclature."

Evans (1950), in studies of the Ontario subsurface, further subdivided the A unit into four members; in ascending order they are A1 evaporite, A1 carbonate, A2 evaporite, and A2 carbonate. Ells (1962) subdivided the F unit within the Michigan basin. On the basis of correlations by sample study and mechanical logs, Ells recognized six distinct and mappable salt zones within the F unit, and numbered these from one to six in ascending order. Salina terminology used in the Michigan basin subsurface is shown on the left side of plate 1. This nomenclature is presently being revised and cannot be considered the offical designation of the Michigan Geological Survey.

Although the Salina of Pennsylvania has been divided (Cate, 1961) by a series of correlation markers on gamma-ray logs, no formal system has been introduced to designate the strata between markers. Nomenclature utilized in the subsurface Salina section in New York is based on terminology applied to the lithologic units recognized in the outcrop area. The lithology of the New York Salina is distinct from that recognized in the Salina of Ohio, and the sections do not appear to be correlative. A discussion of Salina nomenclature in New York is therefore omitted.

In the outcrop area of northern Ohio, the Bass Islands Group is divisible into the Put-in-Bay Formation and the Raisin River Formations. A review of the literature indicates that the formations recognized at the outcrop have not been differentiated in the subsurface on the basis of sample of geophysical log study.

NOMENCLATURE USED IN THIS REPORT[3]

A preliminary comparison of geophysical logs and lithologic descriptions from wells in Ohio with the same subsurface information from wells in adjacent regions indicates that the stratigraphic units of upper Niagaran and Cayugan age in Ohio are lithologically similar to the units of the same age in Michigan, Ontario, and Pennsylvania, but distinct from those of New York and Indiana.

The Lockport Group is present throughout Ohio and in adjacent areas, and presents no problems in correlation in the subsurface. It is a continuous stratigraphic unit, easily recognized from lithologic description or gamma-ray log character. Subdivision of the Lockport Group is discussed in a later section.

The stratigraphic nomenclature proposed by Landes for the Salina Group of the Michigan basin has been shown to be applicable to the Ontario section by various authors. Because this nomenclature is well established and because the Salina units of the Pennsylvania and Ohio section have no prior proposed designation, the writer has utilized the nomenclature of Landes in discussing the various units of the Salina Group in Ohio.

The overall similarities of the gamma-ray log character, and its indicated lithology, between the Michigan and Ohio Salina sections are illustrated on plate 1. Various indications, of a more detailed nature, that the Michigan terminology is applicable to the Ohio subsurface Salina section are presented in the discussion of stratigraphy. A satisfactory method of differentiating formations of the Bass Islands Group in the subsurface has not been described by previous workers.

3. The terminology used by the Ohio Division of Geological Survey for the Silurian of Ohio is in the process of revision. The terminology used in the present report has not been revised and represents Survey usage at the time the report was written.

STRATIGRAPHY

> "A rather obvious comment should be made at this point, and underlined for those unfamiliar with the practices of Appalachian subsurface geology, that correlations involving opinions on stratal continuity are handicapped by the absence of paleontological data. Because of the almost total absence of such data from the subsurface the stratigrapher working in this region is in almost complete paleontological darkness."

This comment by Cate (1961) about the Pennsylvania subsurface applies equally well to the Ohio section.

This investigation is based entirely upon rock-stratigraphic units that can be defined from available subsurface data. The age connotation applied to these strata is based on lateral correlations to the outcrop area, where exposures occupying the same stratigraphic position have been designated by earlier workers to be of a specific age.

Each of the stratigraphic intervals of the upper Niagaran and Cayugan section recognized in the subsurface of northeastern Ohio is discussed as an individual unit. Also included under separate headings are descriptions of the important contacts included in or limiting the stratigraphic section investigated: the Clinton-Lockport, the Niagaran-Cayugan, the Salina-Bass Islands, and the Silurian-Devonian contacts. The upper and lower limits of a particular unit and its relationship to underlying and overlying sedimentary rocks is presented in the section pertaining to that unit. The discussion of each stratigraphic unit is presented in four parts: "Lithology", "Thickness and Distribution", "Distinguishing Character", and "Stratigraphic Relations".

NIAGARAN SERIES

The "Niagaran Series", a term proposed by J. Hall in 1842, includes strata of Clinton and Lockport age. The shales of the uppermost formation of the Clinton Group are considered the base of the drillers' "Big Lime", and therefore the base of the stratigraphic section investigated by the writer.

Clinton-Lockport Contact

Ideally, this contact is a lithologic break between the shales of Clinton age and the overlying carbonate rocks of Lockport age. Locally there is a sharp contact, but in the majority of wells studied, there are transitional dolomitic shales and argillaceous dolomites occupying a zone between the two groups. The writer has included the transitional zone in the Lockport Group.

Lockport Group

The term "Lockport" was proposed by J. Hall in 1839 for the limestones excavated during construction of the Erie Canal at Lockport, New York. Although "Lockport"

has been used in a formational sense[4], most of the state geological surveys in the eastern United States and the U. S. Geological Survey presently consider Lockport to be of group rank. Because of this and the fact that stratigraphic units of formational rank have been assigned to part of the Lockport Group in outcrop sections of Ohio, the writer uses the term in a group sense in this report.

The Lockport is considered to have a biogenic origin, rather than a precipitated origin. Descriptions of the Lockport record abundant organic material; the Niagaran reefs exposed in Illinois, Indiana, and Ohio are classic examples of Paleozoic bioherms.

Because of the biogenic aspect of the Lockport, it would be expected that the areas of thickest Lockport indicate regions conducive to organic growth, such as shallow water along the basin margins. Conversely, thin sections of Lockport rocks indicate restricted organic growth, such as would be expected in the deeper water of basin interiors. This relationship is recognized between the interior of the Michigan basin and its margins.

Lithology. - Although the lithologic characteristics of the Lockport Group vary both laterally and vertically within the project area, the group is always composed of dolomite; no anhydrite or limestone was observed in the samples examined. The color of the Lockport, although varying from dark brown to white, is usually brown to tan in the subsurface section of eastern Ohio. The color lightens progressively westward; and in the western part of the area the predominant colors in the section are gray and white.

In some areas the lower part of the Lockport, an interval as much as 80 feet thick, is a sequence of interbedded shales and dolomites which probably represents a transitional phase between the Clinton and Lockport Groups (B2, B4, C6, E6, and F5).[5] In other areas, however, a sharp, well-defined break marks the contact between the Clinton and Lockport (C2 and D6).

Directly below the Niagaran-Cayugan contact there is a zone in many wells which has the drilling characteristics of a sandstone. This zone, a dark brown, finely crystalline dolomite, as much as 40 feet thick, was named "Newburg sand" by the drillers when first encountered in Cuyahoga County in the early 1900's. The cuttings from this unit resemble a fine sand, but examination of the sample under magnification indicates that the individual grains are rhombohedrons of dolomite. At the present time, any zone in the Lockport with the above characteristics is called "Newburg".

Thickness and Distribution. - Within the area of this study, the Lockport ranges in thickness from a minimum of 55 feet in northwestern Licking County to a maximum of 521 feet in northeastern Morrow County. However, these maximum and minimum thicknesses are of minor importance in comparison with the overall pattern presented by the Lockport isopach map (fig. 7).

This map indicates a relatively thin area, with a thickness of less than 180 feet, in Lorain, Cuyahoga, Medina, Wayne, and Ashland Counties, surrounded by a thicker Lockport section. The thin area indicated by well D5 (pl. 5) in Delaware County and well C1-D6 (pls. 4 and 5) in Licking County is possibly a continuation of the thin area to the north. Considering the biostromal-biohermal nature of the Lockport Group, the pattern suggests a basin during Lockport time in the areas of minimum thickness, surrounded by a shelf upon which conditions were conducive to the

4. The U.S. Geological Survey uses Lockport in a formational sense, applying it to the dolomite that underlies the Salina formation and overlies the Clinton formation in New York and Michigan. Wilmarth (1938).

5. The letter-number combinations in parentheses refer to wells illustrated on the cross sections. The reader can refer to these wells on the appropriate cross section plate.

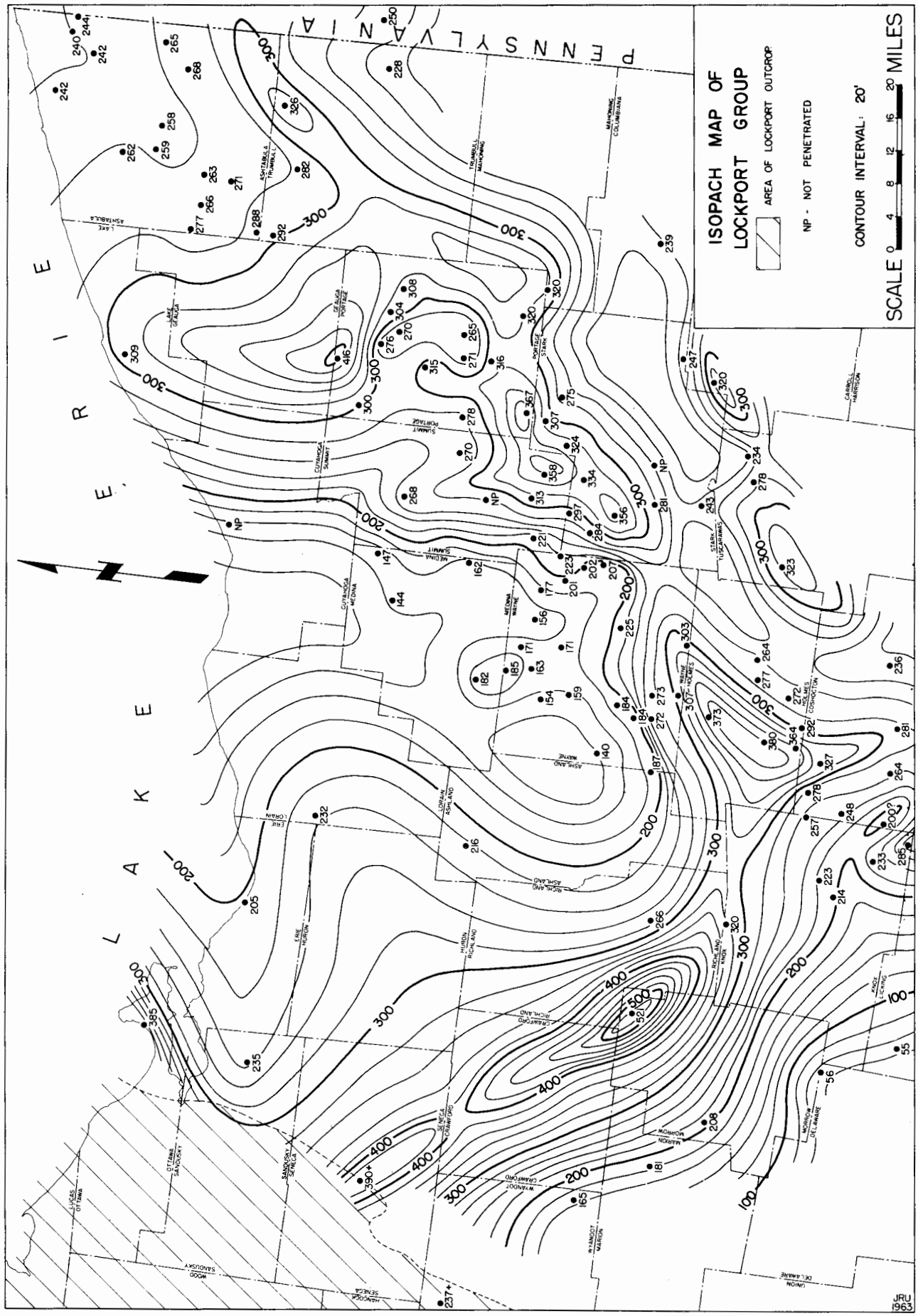
ISOPACH MAP OF
LOCKPORT GROUP
AREA OF LOCKPORT OUTCROP
NP - NOT PENETRATED
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU
1963

Figure 7

growth of calcareous organisms. In Ontario, a basin area with no evidence of reef growth is postulated by Pounder (1962). The evidence indicates that during Lockport time a local north-south trending basin existed beneath areas of Ohio, Lake Erie, and Ontario.

Distinguishing Character. - The most easily recognized character associated with the Lockport Group is the relative purity of the dolomite. The lithologic variations within the group are of little value in differentiating between the Lockport and the other dolomites.

The gamma-ray log exhibits, as expected for a relatively pure dolomite section, a character of low radioactive intensity. The lower limit of the group is somewhat problematic but, for the purpose of this investigation, the distinct break at the shale-dolomite contact is considered the top of the Clinton Shale (base of the "Big Lime"). This marker, illustrated on the gamma-ray logs from wells B7, B8, and B9 (pl. 3), was traced throughout northeastern Ohio. It should be noted however, that in some wells, such as B3, B4 (pl. 3), and C8 (pl. 4), this horizon appears to be within the shale section below the base of the Lockport.

The upper limit of the group is recognized by the change in lithology from the dense, argillaceous, anhydritic carbonate rocks of the Greenfield Formation to the pure, sucrosic-textured dolomite of the underlying Lockport. The unique character represented on a gamma-ray log at the base of the Greenfield (pl. 1) can also be used for recognizing the upper limit of the Lockport.

Stratigraphic Relations. - The Lockport is an easily recognized and continuous rock unit within the subsurface section of Ohio and adjacent regions. The group presents no problems in regional stratigraphic correlations.

Recent studies of Alguire (1962) and Pounder (1962) have established methods for differentiating units of the Lockport in Michigan and Ontario. The gamma-ray character and lithology upon which Alguire and Pounder base their subdivision of the Lockport is, in part, recognizable in the Ohio section. The "shoulder" illustrated on plate 1 and evident on the right half of cross section B-B' (pl. 3), is probably the horizon separating the lower and middle units. The "Newburg sand" may be the Ohio equivalent of the upper unit. More detailed study is necessary, however, to confirm the continuity of the various stratigraphic units from Michigan and Ontario, to Ohio. The formations described in the outcrop are not recognized in the subsurface Lockport section.

NIAGARAN-CAYUGAN CONTACT

The presence of an unconformity at the Niagaran-Cayugan contact in the Michigan basin region has been a subject of controversy for several years. Ells (1962), presents a summary of earlier studies and concepts, and states:

> "Opinion seems to favor at least local areas of subaerial erosion of Niagaran rocks prior to or contemporaneous with the deposition of Salina sediments. If the question of unconformity cannot be adequately resolved by examination of these rocks in outcrop, it seems unlikely that subsurface studies can furnish the answer."

The evidence from wells examined by the writer indicates that the Niagaran-Cayugan contact is a conformable one in the subsurface of northeastern Ohio; however, the statement by Stout and Lamey (1940): "One of the most definite unconformities appearing at the surface in Ohio is that between the Monroe (Cayugan) and Niagara

groups of rocks." indicates the possibility of local areas of unconformity in the subsurface east of the described exposures.

CAYUGAN SERIES

"Cayugan period or group" was proposed by Clarke and Schuchert in 1899 for the section of carbonate rocks exposed around the north end of Cayuga Lake, New York. This group of sedimentary strata, with similar lithologic and faunal characteristics, is definitely Upper Silurian in age. In the Michigan basin area, the rocks of Cayugan age consist of the Salina and Bass Islands Group.

Salina Group

In 1863, Dana proposed the term "Salina formation" for the sedimentary section containing the Guelph Limestone and the Onondaga Salt Group. Presently the term is restricted to the section containing salt in the Appalachian-Michigan basin area.

During the past 100 years, many terms have been applied to this group in the outcrop sections of the various states in the Appalachian region. Most of the outcrop nomenclature, however, does not precisely subdivide the subsurface section. The writer therefore uses the Michigan basin subsurface Salina nomenclature proposed by Landes in 1945 to discuss the group.

Greenfield Formation (A Unit)

The name "Greenfield" was proposed by E. Orton in 1871 for a section of dolomite disconformably overlying the "Niagaran" Dolomite and disconformably underlying the Ohio Shale. The type section for this formation is near the village of Greenfield, Highland County, in southwestern Ohio.

Stout (1941) describes the Greenfield Formation, from exposures throughout western Ohio, as a true dolomite, bluish-gray to dark brown in color, dense to granular, and commonly in beds ranging from 2 to 18 inches in thickness. In western Ohio, the Greenfield disconformably overlies rocks of Niagaran age. The upper contact with younger Salina beds is conformable, except in southwestern Ohio, where the Greenfield was exposed and eroded during the Silurian-Devonian hiatus.

Lithology. - In the subsurface of northeastern Ohio, the rock unit is a dolomite, gray to brown, dense to crystalline, argillaceous, anhydritic, and contains bedded anhydrite and shale stringers. In Sandusky, Lorain, and Medina Counties, limestone was observed in the samples from several wells (See well A5, pl. 2). The limestone, dark brown to black, dense, and asphaltic, in intervals from 10 to 40 feet in thickness, occurs in the lower half of the unit.

A sequence of bedded anhydrite overlain by a dolomitic shale or argillaceous dolomite is commonly observed near the base of the Greenfield. This sequence also occurs near the middle of the formation in some wells in the Medina, Lorain, and Sandusky County area.

Thickness and Distribution. - The thickness of the Greenfield ranges from 30 to more than 200 feet (isopach map, fig. 8). The thickest section of the formation occurs in Medina, Lorain, and Cuyahoga Counties, where its thickness exceeds 200 feet; and in the Morrow, Delaware, and Licking County area where a maximum thickness of 252 feet was recorded. These areas of thickest Greenfield correspond to the areas of thin Lockport.

East of the area of maximum thickness in Medina, Lorain, and Cuyahoga Counties, the Greenfield Formation thins abruptly and maintains a uniform thickness of 60 to 80 feet throughout the eastern part of the area involved in this study. The rock unit also thins to the south and west, but because of the lack of control data, it is not possible to define a zone of abrupt thinning.

The Greenfield crops out along the east side of the Cincinnati-Findlay arch from Sandusky to Highland Counties. The exposure and pinchout of the unit in the western part of the area of this investigation is the result of post-Paleozoic, preglacial erosion across the Findlay arch; however, the thinning and pinch-out of the Greenfield in southwestern Ohio is, in part, the result of exposure during late Silurian and early Devonian time.

Distinguishing Character. - The contact of the Greenfield Formation with the underlying Lockport Group is recognized in well samples by the abrupt change from an argillaceous, anhydritic, dense dolomite to the relatively pure, sucrosic, crystalline dolomite of the Lockport. In the area of maximum thickness the basal portion of the Greenfield consists of a dolomitic shale underlain by a bedded anhydrite. The character on a gamma-ray log produced by this sequence is distinct and easily recognized (pl. 1). The writer places the lower limit of the Greenfield at the base of the anhydrite.

The upper limit of the formation is placed below the lowest salt unit (or its anhydrite facies) of the Salina in Ohio. This contact is recognized on a gamma-ray log by the unique character at the base of the overlying B unit (pl. 1).

The gamma-ray log from the King - No. 1 Hawley well (E4, pl. 6), in Westfield Township, Medina County, exhibits characteristics which are observed on many gamma-ray logs of the Greenfield in the area of maximum thickness. The writer therefore considers this log typical of the Greenfield in the subsurface of northeastern Ohio.

Stratigraphic Relations. - Landes (1945) states:

> "The dolomitic beds of unit A crop out in northern Ohio, immediately north of the outcrop of rocks of Niagara age. There they have been called the Greenfield dolomite member of lower age. However, the cross-section proves that unit A is of Salina age."

Alling and Briggs (1961) recognize correlation of at least part of the A unit with the Greenfield, but did not suggest replacement of the informal term "A Unit" by the formal term "Greenfield".

The A unit, as proposed by Landes, was further subdivided by Evans (1950) into four members; in ascending order they are A1 evaporite, A1 carbonate, A2 evaporite, and A2 carbonate. Landes reported a maximum thickness of 1,105 feet for the A unit in Bay County, Michigan; the two salt members of the A unit in Bay County having an aggregate thickness of 872 feet. Subsequent drilling in deeper parts of the Michigan basin has not encountered an appreciably greater thickness.

The correlation section (pl. 1) indicates that the salt facies of the A1 evaporite is present only within the deeper parts of the Michigan basin. No publications describe A1 salt occurring outside the political boundaries of the state of Michigan.

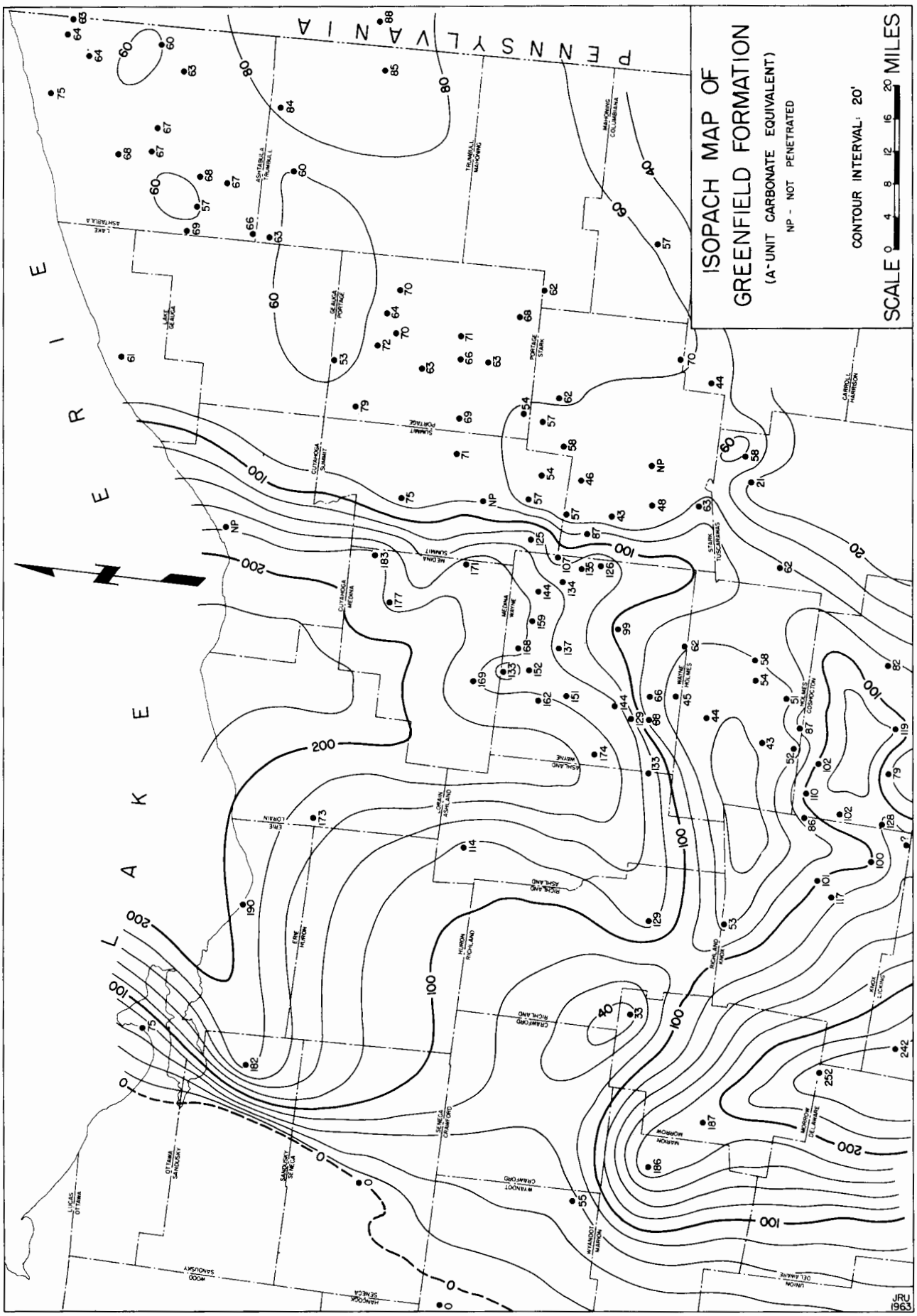
ISOPACH MAP OF
GREENFIELD FORMATION
(A-UNIT CARBONATE EQUIVALENT)
NP - NOT PENETRATED
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
ERIE
LAKE
JRU
1963

Figure 8

Hewitt (1962) states that in Ontario: "The lower salt bed in the A2 unit occurs only within the Sarnia-Goderich salt area. It is not present in the Windsor or Chatham salt basin." In other words, it occurs only within the Michigan basin proper and is not found on the west flank and crest of the Algonquin arch. In describing the A unit of Ontario, Sanford and Brady (1955) state that:

> "Both the A1 and A2 are buff to light brown, granular dolomite at the top, becoming darker in colour and more argillaceous and dense towards the base. The lower part of A2 may contain a thick bed of salt (lower salt), up to 125 feet in thickness, or in its absence a thin bed of anhydrite, making the two units easy to distinguish."

Many authors refer to the thinning of the A unit evaporites and the replacement of salt by anhydrite outward from the Michigan basin center and over the crests of pinnacle reefs. South of Ontario, across Lake Erie in Ohio, the lithology as described above is encountered in well samples in Medina, Lorain, and Erie Counties. It was not possible to ascertain if both the A1 and A2 carbonates, separated by the A2 evaporite, are represented; or if only the A2 carbonate with interbedded anhydrite is present. No salt was observed in any of the well samples from A unit.

This stratigraphic unit is identifiable in the subsurface throughout the northeastern Ohio area and can be traced to the outcrop section where the term "Greenfield" has been applied. The continuity of the Greenfield from the outcrop sections in western Ohio to the subsurface section in northeastern Ohio is illustrated on cross sections A-A' (pl. 2) and D-D' (pl. 5).

The foregoing evidence indicates that the carbonate members of the A unit are represented in the Ohio subsurface. However, the writer is of the opinion that "Greenfield Formation" is a more appropriate term than "A unit" for designating this stratigraphic sequence in Ohio. The term "A unit" implies a salt-carbonate sequence which is non-existent within the unit in Ohio; the name "Greenfield" is a formal term and well established in the Ohio literature; and most important, the lithology of the Greenfield in outcrop is recognizable in the subsurface section.

B Unit

The "B Unit" is a term proposed by Landes (1945) for a salt member of the Salina overlying the carbonate-salt sequence of the A unit and underlying the C shale unit. Landes reported its thickness in Michigan as rather uniform, ranging from 240 to 275 feet. This is the No. 4 Salt as numbered by the salt companies operating in Ohio.

Lithology. - The lithology of the B unit varies from an interbedded salt and shale sequence in Lake County to an argillaceous, anhydritic dolomite or lutite[6] in the western part of the area of this study. Outward from the place of maximum thickness in the Lake County region an anhydrite facies replaces the salt. The area in which salt occurs in the B unit is shown on figure 9. Sample examination indicates that the anhydrite beds become progressively thinner and the shale members become progressively more dolomitic in a westerly direction.

6. The term "lutite" has been utilized in this report to define a lithology which cannot properly be described as dolomite, shale, or anhydrite. As applied by the writer, a lutite is a dense to silty rock composed of varying amounts of calcareous, argillaceous, and evaporitic material. The sample descriptions in Appendix B include the approximate percentage of each constituent in the lutite; however, the intervals thus described defy classification on the basis of visual examination alone.

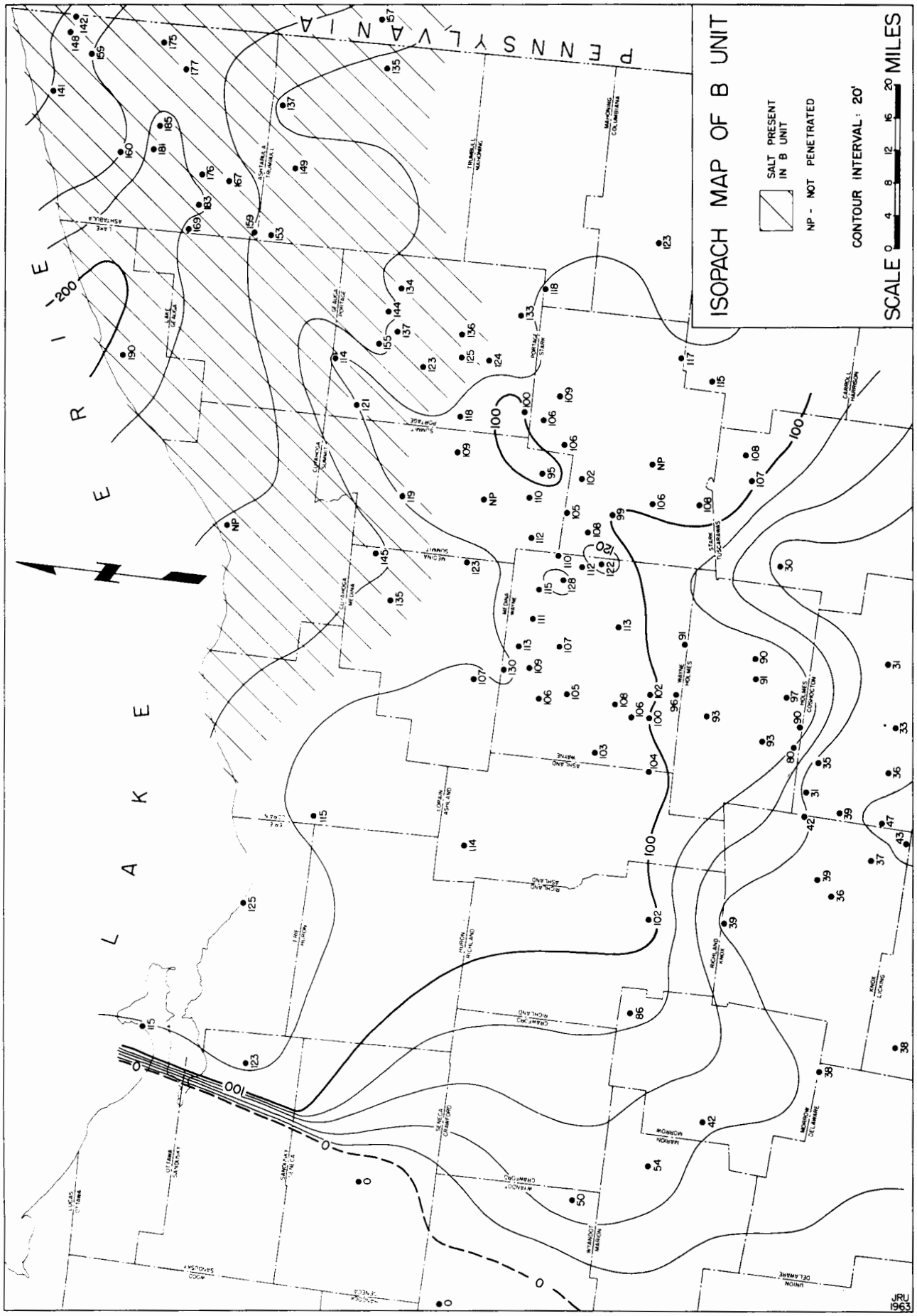
ISOPACH MAP OF B UNIT
SALT PRESENT IN B UNIT
NP - NOT PENETRATED
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU 1963

Figure 9

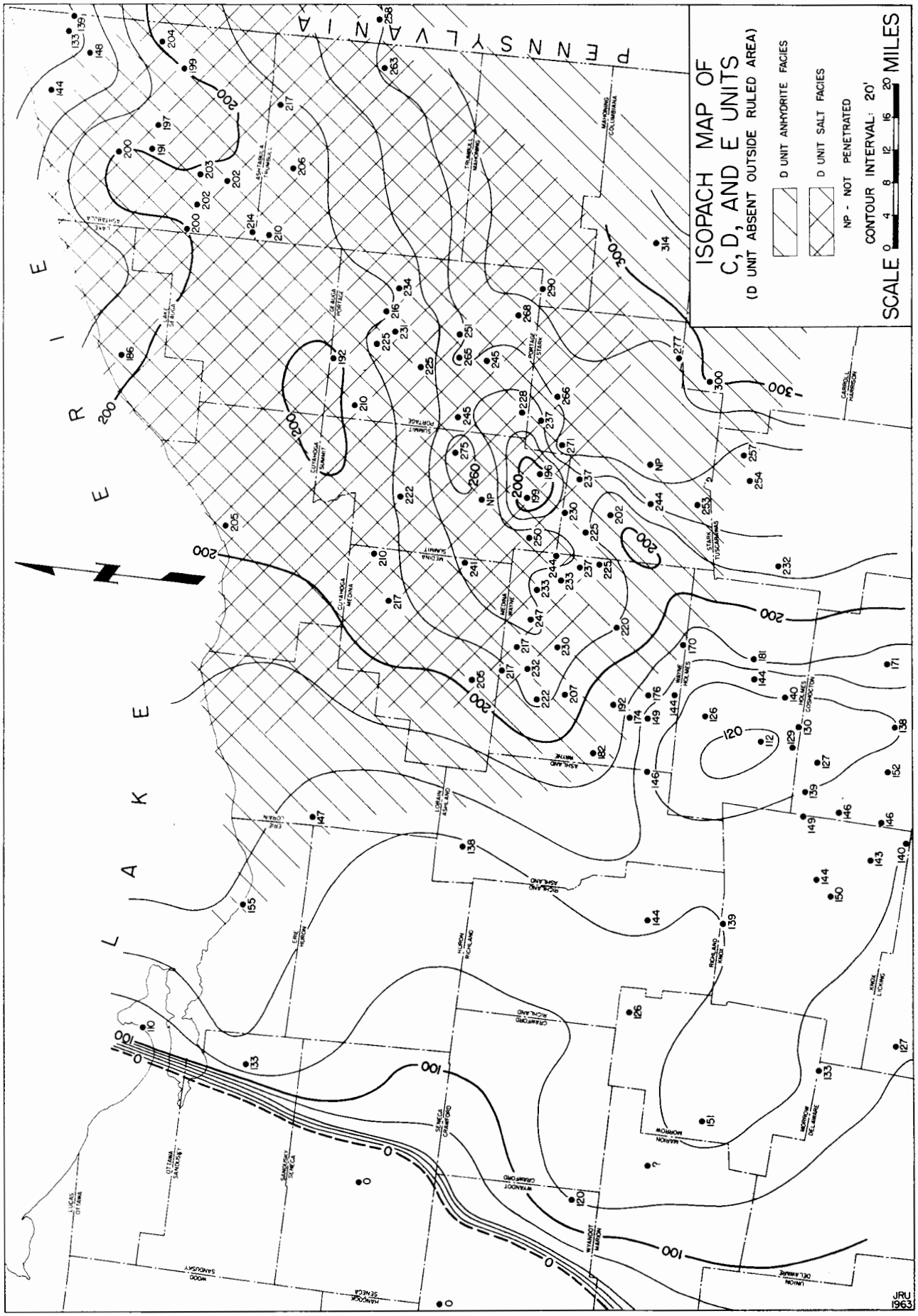
ISOPACH MAP OF
C, D, AND E UNITS
(D UNIT ABSENT OUTSIDE RULED AREA)
D UNIT ANHYDRITE FACIES
D UNIT SALT FACIES
NP - NOT PENETRATED
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU
1963

Figure 10

Thickness and Distribution. - The maximum thickness recorded in northeastern Ohio is in Lake County, where the unit exceeds 200 feet in thickness (isopach map, fig. 9). The lithology displayed in the samples from well A7-G1 (pls. 2 and 8), located within the area of maximum thickness, is typical of the B unit in Ohio. The unit appears to be thickest in an elongate area trending northwest-southeast in Lake and Ashtabula Counties, and thins progressively outward from the thick area in a northeast and southwest direction. The B unit is not truncated below the Silurian-Devonian unconformity within the area of investigation. It is exposed and truncated along the Findlay arch, however.

Distinguishing Character. - The lower limit of the B unit is placed at the base of the lowest salt present in Ohio. Where the anhydrite facies has replaced the salt, the unique character on a gamma-ray log (illustrated on plate 1) defines the base of the B unit. This character is caused by a thin shale overlying a split evaporite bed and can be recognized on most of the gamma-ray logs shown on the cross sections.

The upper limit of the B unit is placed at the top of a continuous evaporite zone within a shale unit, although the shale members above and below the evaporite have similar lithology. In the area of Lake and Ashtabula Counties (A7, B11, and B12), this upper shale member of the B unit should possibly be included with the overlying C unit. However, in other parts of the area included in this study, the upper shale is interbedded with anhydrite and is similar to the underlying part of the B unit (E5, E6, and E7).

Stratigraphic Relations. - Lithologically, the B unit of the Michigan basin is practically a pure salt with the upper half containing numerous shale-carbonate stringers. This rock unit in Ohio, commonly known as the "dirty" salt, is a sequence of interbedded shale and salt.

The basic reason for placing the upper limit of the B unit within a generally homogeneous shale sequence is illustrated on plate 1. In the Michigan basin, there is a shale-carbonate member within the B unit which is separated from the C unit by a thin evaporite bed. This member appears to be correlative with the lower part of the shale sequence recognized in Ohio.

To the east, in Pennsylvania, a B-unit equivalent is recognizable in the subsurface, consisting of a series of interbedded evaporite and shale-carbonate members. Salt is present in the unit east of Ashtabula County, Ohio.

C Unit

The C Unit as defined by Landes is a sequence of shales and argillaceous dolomites commonly grayish-green in color and ranging in thickness from 60 to 160 feet. The unit is thinnest in the interior of the Michigan basin and thickens outward without regularity.

Lithology. - The samples which were examined indicate that the C unit is characteristically a shale, gray to green, dolomitic, and anhydritic. In some well samples from northeastern Ohio, the unit could properly be described as an argillaceous dolomite. The most easily recognized lithologic character of the unit is its green color, which is most distinct when the lithology is a true shale.

Thickness and Distribution. - The thicknesses of units C, D, and E change in direct proportion to one another. Because of this, and the fact that the amount of thickness variation of the three units is relatively small in comparison with other members of the Salina Group, these units are grouped together in fig. 10, and the isopachs represent their combined thicknesses.

The isopach map indicates gradual thickening to the south and east. The thickest section occurs approximately along the axis of thickest total accumulation illustrated by the "Big Lime" isopachs (fig. 5); a portion of the thinning can be attributed to the absence of evaporites outside the basin of deposition.

The C unit has a very uniform thickness of 30 to 40 feet. The abnormally thick sections recorded in the Michigan basin were not observed within the area of investigation.

Distinguishing Character. - The C unit displays the highest radioactive intensity of any interval within the "Big Lime". In orienting a geophysical log, the writer utilized the easily recognized C shale-unit as a starting point for correlation purposes.

The lower limit of the C unit can be recognized by the underlying thin evaporite zone which is present throughout the area of investigation. The upper limit is also easy to distinguish in areas where the D evaporite-unit overlies the C shale-unit. In regions where the D unit is absent because of nondeposition, the contact with the overlying E unit is gradational; however, the C unit is generally more argillaceous than the E unit.

Stratigraphic Relations. - The green-shale lithology and the gamma-ray log character of the C unit are readily identified from subsurface data. A review of the recent literature and an examination of a few geophysical logs from various states indicate that the unit is the most extensive lithologic sequence within the Salina Group and is an excellent correlation marker for regional stratigraphic studies in the Michigan-Appalachian basin area. The writer is of the opinion that the unit represents a tongue of the Vernon Shale of New York.

The term "Tymochtee slate" was applied by N. H. Winchell (1873) to an exposure of dolomitic shale and/or argillaceous dolomite along Tymochtee Creek in Section 34, Crawford Township, Wyandot County; the upper and lower limits of the unit so named are not exposed. The Tymochtee Formation, as presently defined, overlies the Greenfield Formation and underlies the Bass Islands Group, an interval represented by units B, C, D, E, F, and G in the subsurface.

Landes (1945) and Alling and Briggs (1961) expressed the opinion that the type section of the Tymochtee could be the exposure of a part of the intervals designated C, E, or G in the subsurface. The present investigation indicates that the G unit is truncated and pinches out, as does the F unit, east of the type section and only the B, C, and E units are present in the area of the exposure described by Winchell. Because of the greater content of argillaceous material in the Tymochtee and the C unit in relation to overlying and underlying sedimentary strata, it is the writer's opinion that the exposed section is part of the Salina Group designated as "C unit" in the subsurface.

D Unit

The term "D unit" was used by Landes to designate a thin evaporite bed between two thicker shale-carbonate sequences. This unit is nearly entirely evaporite, with a thin shale-carbonate parting near its middle. Landes reports its thickness as ranging from 30 to 65 feet. The D unit is known as the No. 3 Salt in Ohio.

Lithology. - The D unit in the Ohio subsurface is an evaporite sequence with a thin shale parting near its middle. The area of salt occurrence in the unit is shown on figure 10; outward from this area, an anhydrite facies replaces the salt. The parting in the unit is a gray to brown dolomitic shale.

Thickness and Distribution. - As explained in the preceding section, the C, D, and E units were combined for the isopach map (fig. 10). The D unit has a maximum thickness of 45 feet; the unit is not recognized beyond the area shown on figure 10 and is considered absent from the section because of nondeposition.

Distinguishing Character. - The D unit is easily recognized on a gamma-ray log by the relatively low radioactive intensity occurring between two thicker units with higher radioactivity (pl. 1). The upper and lower limits of the unit are placed at the top and bottom of the evaporite sequence.

Stratigraphic Relations. - Stratigraphic position, lithology, and gamma-ray character indicate equivalent units in the Michigan basin and in Ohio. The D unit can also be recognized in the subsurface of Pennsylvania, and could possibly be continuous into New York.

E Unit

The E unit of the Michigan nomenclature has a very uniform thickness, reported by Landes as ranging from 92 to 122 feet. The lithology varies from a red shale to an argillaceous dolomite with anhydrite partings.

Lithology. - The E unit in Ohio shows all of the varied lithology of the Salina; dolomite, anhydrite, salt, shale, and lutite (appendix B). The sequence differs, but an argillaceous dolomite or shale always is present at the top of the unit (pl. 1). The E unit is commonly a brown, argillaceous, anhydritic dolomite (lutite) with thin anhydrite interbeds and occasional salt lenses.

Thickness and Distribution. - The E unit was combined with the D and C units for the isopach map (fig. 10) as explained previously. Its thickness ranges from 70 feet in the western part of the area of investigation to 200 feet in Mahoning County. The unit is exposed and pinches out along the Findlay arch.

Distinguishing Character. - Where the overlying and underlying evaporite units are present, the E unit is readily identified from samples or gamma-ray logs (pl. 1). Near the basin margin, in the western part of the thesis area, the absence of the evaporites make a distinction more difficult; however, the relatively greater amounts of argillaceous material in the overlying F unit and the underlying C unit will usually provide a means for identification of the E unit if samples or gamma-ray log characteristics are studied.

Stratigraphic Relations. - The similarity of the gamma-ray character, lithology, and stratigraphic position of the interval in Ohio with the E unit in Michigan and Ontario indicates continuity between the areas. The unit is also identifiable east of the area of this investigation, in Pennsylvania.

F Unit

Landes defined the F unit as a series of salt beds separated by dolomite, argillaceous dolomite, and shale partings. Ells (1962) recognized six distinct salt beds in the F unit and numbered them consecutively in ascending order (pl. 1).

Lithology. - In northeastern Ohio, the F-unit lithology varies from interbedded salt and shale in Portage County to argillaceous, anhydritic dolomite and lutite in the

western part of the area involved in the present study. The lithologic variation is similar to that described in the B-unit discussion.

Four evaporite zones can be recognized in the F unit of Ohio (pl. 1). The lowest salt of the F unit in Michigan, designated as F Salt 1, is known as the No. 2 Salt in Ohio. The F Salt 2 of Michigan is known as the No. 1 Salt in Ohio and is the youngest salt bed present in the Lake County region.

The presence of the various F salt-members in northeastern Ohio is indicated in figure 11. Outside the areas illustrated, the salt is replaced by an anhydrite facies.

Thickness and Distribution. - The unit ranges in thickness from 60 feet in the area of no evaporite deposition to more than 300 feet in Portage, Mahoning, and Columbiana Counties (isopach map, fig. 11). Well F4 (pl. 7) is representative of the F-unit lithology in the area of maximum thickness. The thickest section of salt deposition occurs along the basinal axis illustrated on the "Big Lime" isopach map (fig. 5), namely a northwest-southeast "trough" through Cuyahoga, Portage, Mahoning, and Columbiana Counties.

Cross sections A-A' (pl. 2), B-B' (pl. 3), C-C' (pl. 4), and D-D' (pl. 5) indicate the truncation of the F unit below the Silurian-Devonian unconformity. Further to the southwest, as illustrated in figure 11, the F unit pinches out beneath the Devonian sedimentary rocks. The unit is exposed along the east side of the Findlay arch, north of Marion County.

Distinguishing Character. - The overall lithologic and gamma-ray log character of the F unit in eastern Ohio is distinctive. Near the basin margin in the western part of the area of investigation, the F unit is not distinguishable from the other units of the Salina without the aid of subsurface correlations from the basin interior.

The lower limit of the F unit is placed at the contact of the lowest evaporite in the unit with the underlying shale member of the E unit. The upper limit of the formation is at the base of the overlying G shale-unit. The character of the overlying G shale-unit in contrast to the evaporite-shale sequences of the F unit is easily identified on gamma-ray logs.

Stratigraphic Relations. - The various salt layers of the F unit are not continuous across the Findlay-Algonquin arch system. However, the similarity of lithologic descriptions and gamma-ray log characteristics of the F unit (pl. 1) is the most conclusive evidence which indicates that the Michigan and Ohio Salina sections are stratigraphically correlative and equivalent.

The thickest F-unit interval occurs in the interior of the Michigan basin, and the two youngest salt members of the F unit are apparently restricted to this region. Outward from the basin interior, the stratigraphic correlation of the interval containing the two youngest F salt-layers and the G unit is problematic. Although the Salina nomenclature is undergoing revision, present opinion (Ells, 1962) is that the lower part of the G unit of the basin margin represents the shale-carbonate partings which separate the younger F-unit salts in the Michigan basin interior.

G Unit

Landes proposed the term "G unit" to designate the interval, shown to be of Salina age, between the uppermost salt layer and the overlying carbonate rocks of the H unit or Bass Islands Group. The lithology of the unit is characteristically an argillaceous dolomite. Locally there are anhydrite and shale stringers, and in northern

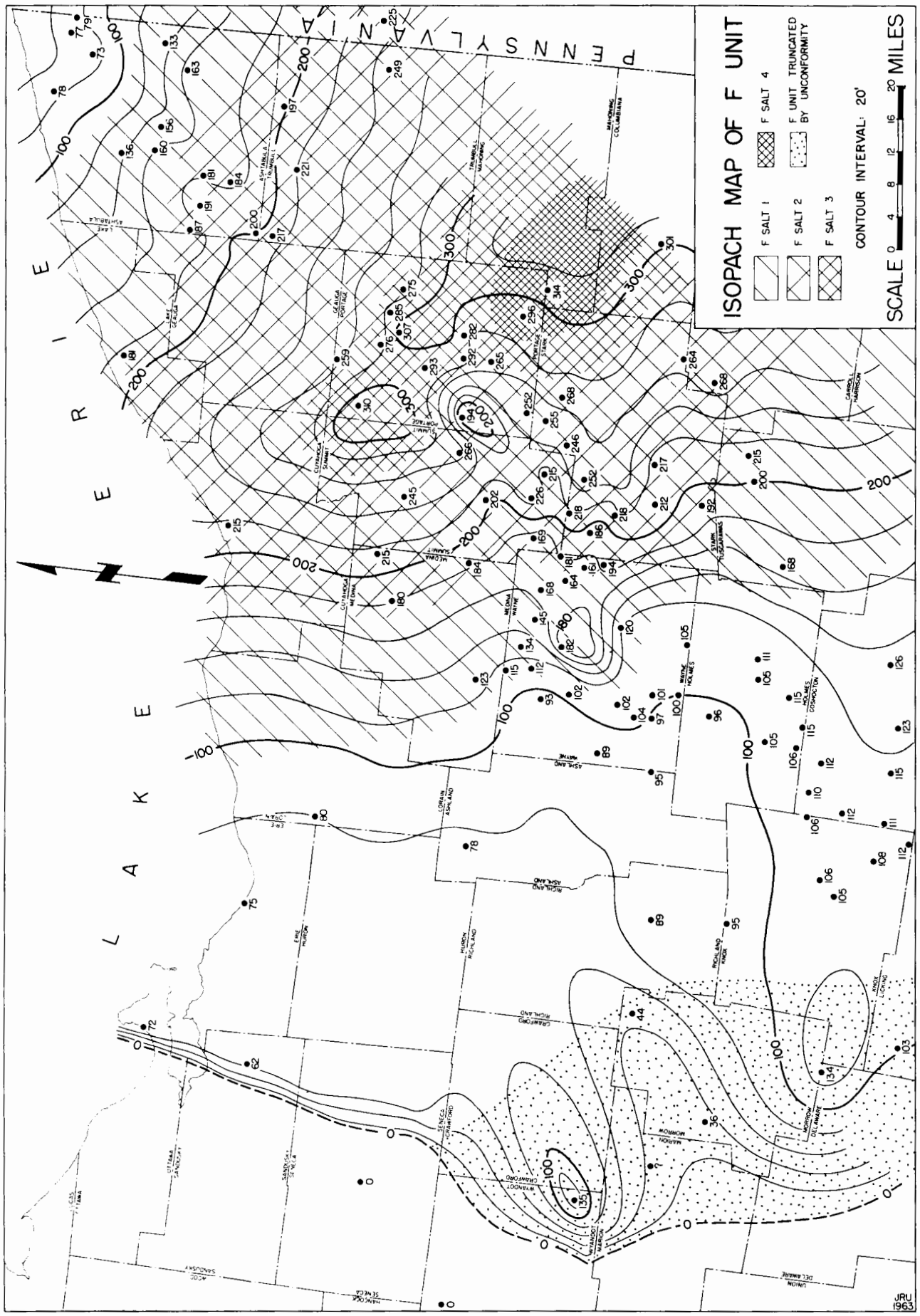
ISOPACH MAP OF F UNIT
F SALT 1
F SALT 2
F SALT 3
F SALT 4
F UNIT TRUNCATED BY UNCONFORMITY
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU 1963

Figure 11

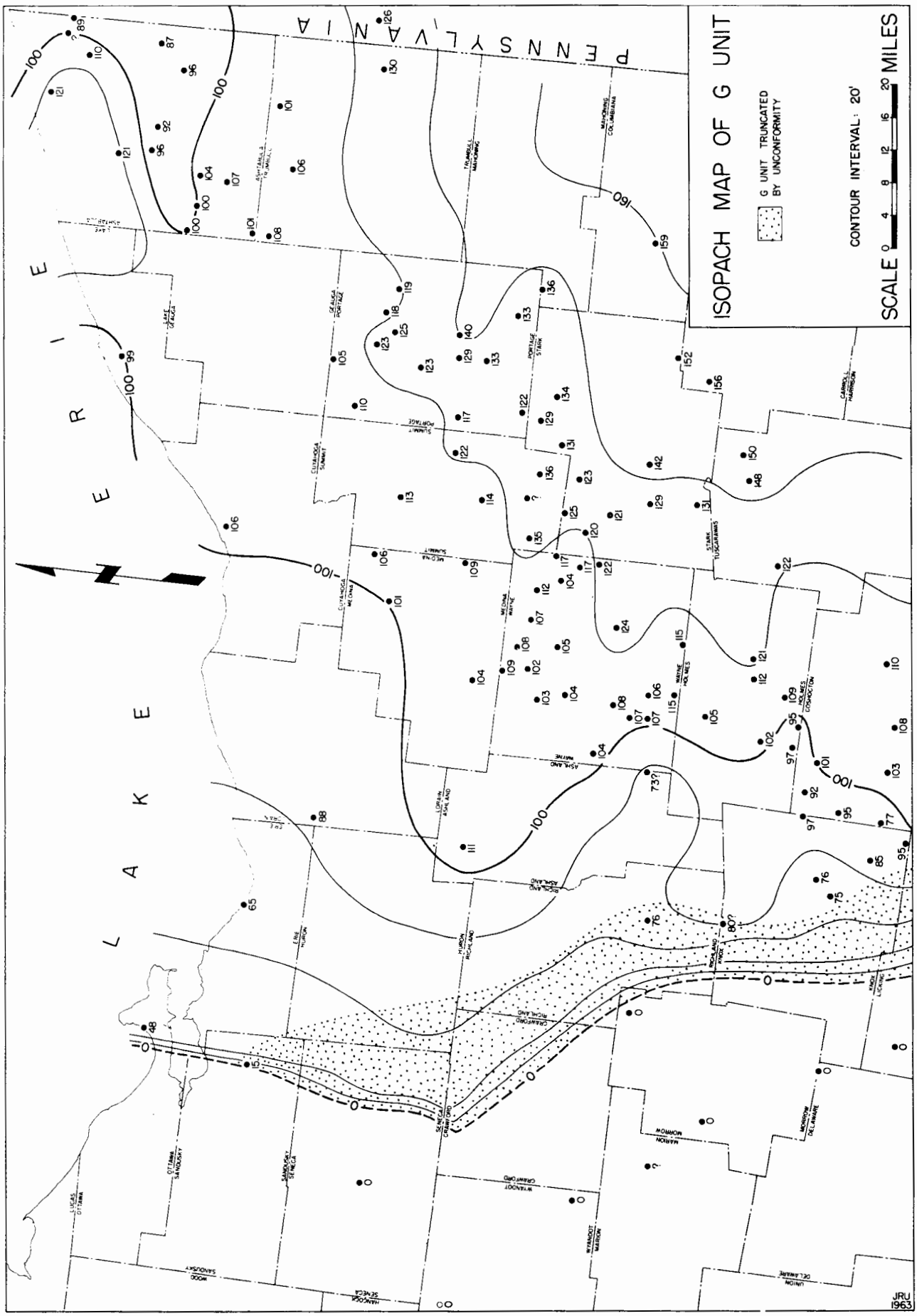
ISOPACH MAP OF G UNIT
G UNIT TRUNCATED BY UNCONFORMITY
CONTOUR INTERVAL: 20'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU 1963

Figure 12

Michigan the interval is composed of brown dolomite overlain by red and green shales. Its thickness was reported by Landes as 80 to 100 feet, but the unit thins rapidly to 40 feet in southeastern Michigan and northwestern Ohio.

Lithology. - The G unit in Ohio is composed of two parts, a lower shale member and an upper anhydrite member (pl. 1). The lower shale is gray to dark brown, dolomitic, and anhydritic, with a few thin, interbedded anhydrite layers. The section is more dolomitic in the western part of the area of this investigation.

The lithology of the upper member varies considerably. In eastern Ohio it is a gray, argillaceous anhydrite or bedded, white, crystalline anhydrite with thin argillaceous partings. To the west, on the basin margin, the dolomitic content is higher, and the rock is a dolomitic shale or lutite with anhydrite partings.

Thickness and Distribution. - The G unit ranges in thickness from 60 to 160 feet. The isopach map (fig. 12) indicates a progressive thickening of the unit in a southeasterly direction, with only a slight suggestion of thickening along the northwest-southeast axis.

The unit is truncated and pinches out below the Silurian-Devonian unconformity as illustrated in figure 12. Along the east side of the Findlay arch, north of Crawford County, the G unit is exposed in outcrops.

Distinguishing Character. - The lower limit can be recognized by the change in lithology from a shale to the evaporite sequence of the F unit. This horizon is easily recognized on gamma-ray logs (pl. 1).

The upper limit is usually distinctive on gamma-ray logs (pl. 1) and also in sample descriptions in the areas where the overlying section of the Bass Islands Group is argillaceous and the upper member of the G unit is anhydrite. In some wells, however, the two intervals are comprised of lutite of slightly different composition and are difficult to differentiate.

Stratigraphic Relations. - The G unit as described in this report is continuous to the east into Pennsylvania. Its correlation with the Michigan subsurface, however, is problematic. The difficulty in correlation is caused by the lack of faunal material for precisely dating the various stratigraphic units. This is discussed further in the following section.

Salina-Bass Islands Contact

In Pennsylvania, Cate (1961) considered the top of the Salina "to be coincident with the first occurrence of bedded anhydrite and/or vugular dolomite filled with anhydrite crystals; a distinctive horizon quite easily recognized in most sample sequences." Further, Alling and Briggs (1961) remarked that:

> "There is little difficulty in separating the Bass Island carbonate rocks from the underlying Salina in either the subsurface or surface occurrences. In the subsurface the top of the Salina is marked by the abrupt transition from gray argillaceous anhydritic dolomite to brown or buff dense dolomite of the Bass Island rocks."

For the purposes of this report, the Salina-Bass Islands contact is placed at the top of the uppermost bedded anhydrite in the Ohio Silurian section. This horizon is easily recognized from sample descriptions and on gamma-ray logs.

When this contact is correlated with the typical Salina section in the Michigan basin interior (pl. 1), it corresponds to a horizon within the G unit. The beds composing the stratigraphic intervals are apparently correlative, however; and any age connotation applied without the aid of fossil evidence is of secondary importance.

Bass Islands Group

The term "Bass Islands" was proposed by Lane, Prosser, Sherzer, and Grabau (1909). This group of rocks, formerly designated "Lower Monroe", occupies the interval between the Salina Group and the overlying Sylvania Sandstone. The type locality is on the Bass Islands in Lake Erie north of Sandusky County, Ohio. Since the term was proposed, several authors have dropped the plural, but the writer prefers "Bass Islands".

The group is divided into the Put-in-Bay Formation and the overlying Raisin River Formation. However, Alling and Briggs (1961) state:

> "There is some doubt whether the separation of the Bass Island into Put-in-Bay and Raisin River formations is wise inasmuch as they are not exposed in any one outcrop and are not distinctive units even in cores from the subsurface. The described faunas of the two formations are not distinctively different."

The group is described as buff, gray, and brown, argillaceous dolomite. A pelletal or oolitic texture is commonly associated with the Raisin River Formation and a brecciated texture is considered to be a characteristic of the Put-in-Bay Formation. Except for these two textural characteristics, the strata of the Bass Islands Group are lithologically similar.

Lithology. - The Bass Islands Group in the subsurface of northeastern Ohio is typically a brown, argillaceous, calcareous dolomite, locally with included anhydrite crystals. The lower 40 to 50 feet of the unit is argillaceous and could correctly be labeled dolomitic shale in some instances. Oolitic or pelletal textures were observed in a few sample sequences in the upper part of the group, but this texture does not appear to be continuous throughout the area of investigation.

Thickness and Distribution. - For constructing the isopach map (fig. 13) the Bass Islands Group and the overlying "Big Lime" carbonate rocks were combined because of the difficulty in distinguishing between them without the aid of sample studies. The map illustrates a definite thickening along the northwest-southeast axis of deposition.

The thickness of the Bass Islands ranges from 60 to 250 feet. The group is truncated and pinches out below the Silurian-Devonian unconformity as illustrated in figure 13. The Bass Islands Group crops out along the east side of the Findlay arch in the vicinity of northwest Erie County and the Bass Islands.

Distinguishing Character. - The Bass Islands Group is a sequence of dolomites between the evaporite rocks of Salina age and the cherty limestones of Devonian age. The lower limit is recognized by the change from argillaceous, brown dolomite to gray anhydrite as described in the foregoing discussion of the G unit.

The writer found no satisfactory method for recognizing the upper limit of the Bass Islands Group from indications shown on gamma-ray logs. A sample sequence will show a change, generally abrupt, from cherty limestones with quartz

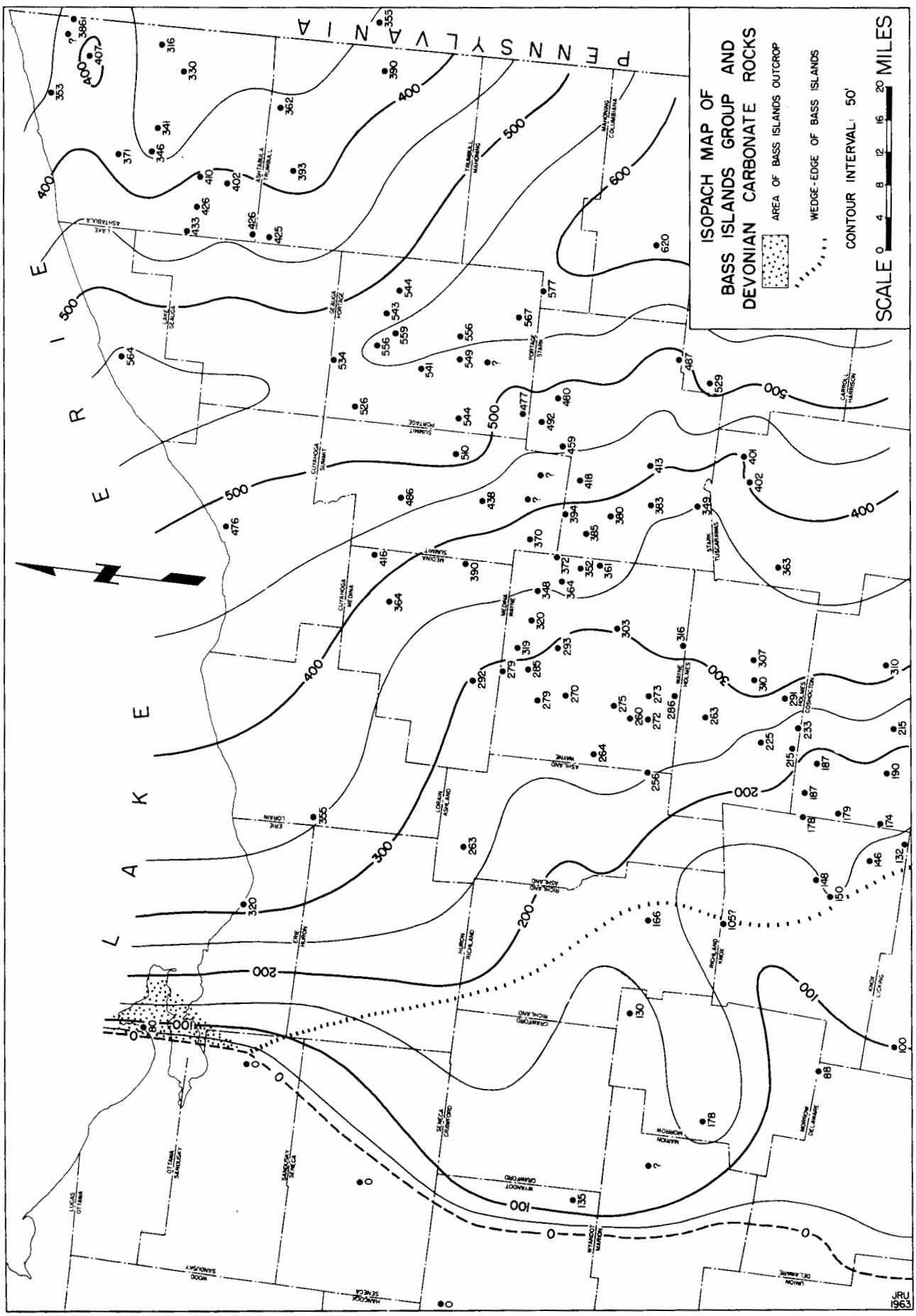
ISOPACH MAP OF
BASS ISLANDS GROUP AND
DEVONIAN CARBONATE ROCKS
AREA OF BASS ISLANDS OUTCROP
WEDGE-EDGE OF BASS ISLANDS
CONTOUR INTERVAL: 50'
SCALE 0 4 8 12 16 20 MILES
PENNSYLVANIA
LAKE ERIE
JRU
1963

Figure 13

grain inclusions to the brown crystalline dolomites of Bass Islands age. In some instances, however, lithology is an unsatisfactory means of differentiating Bass Islands and Helderberg rocks. This is discussed further in the following sections.

Stratigraphic Relations. - The Bass Islands Group in Ohio is correlative with similar rock sequences in Michigan, Ontario, and Pennsylvania. The lower limit, in contact with rocks of the Salina Group, can be traced with relative certainty; however, in certain areas, the Silurian-Devonian contact, the upper limit of the group, is rather difficult to determine from subsurface data.

SILURIAN-DEVONIAN CONTACT

Throughout the northeastern Ohio subsurface, evidence indicates an unconformity at the upper limit of the stratigraphic section being investigated. From east to west, progressively older Salina units are truncated and wedge-out below Devonian strata. The interval between Silurian and Devonian rocks contains clean, reworked sandstones which are apparently the product of a transgression over an exposed surface. The exposures of the contact in the western Ohio outcrop area demonstrate many of the characteristics associated with an unconformity.

In rock sequences which display an abrupt change from the typical lithology of the Lower Devonian, arenaceous and siliceous limestone, to the crystalline dolomite of the Bass Islands, the contact is easily recognized. In eastern Ohio, however, the interval near the Silurian-Devonian boundary displays transitional lithology (dolomitic limestone and calcareous dolomite) making it difficult to recognize a contact between the Bass Islands of Silurian age and the Helderberg of Devonian age. Apparently there was, in this area, continuous carbonate rock deposition from latest Silurian to earliest Devonian time.

In discussing the Silurian-Devonian contact in Pennsylvania, Cate (1961) stated:

> "The upper boundary of the Bass Island is in some places difficult to place. It is not difficult to determine this boundary where the Oriskany sandstone overlies the Bass Island because that boundary is presumably an erosional surface; with strongly contrasting lithologies above and below the horizon. But in all of Pennsylvania, except the northernmost part, the Helderberg group is found between the Oriskany and the Bass Island (or its lithologic equivalent), and in this situation the top of the Bass Island is rather difficult to recognize, for the contact is between carbonates of the Helderberg and Bass Island types."

More stratigraphic and paleontologic studies of this interval are required to establish the relationship between the Bass Islands Group and the Helderberg rocks.

SUMMARY AND CONCLUSIONS

The formations of the Lockport Group identified in the outcrop section of western Ohio are not recognizable in the subsurface section. There are some stratigraphic units of the Lockport which are apparently correlative in the subsurface within Ohio

and possibly correlative with subsurface units in Ontario and Michigan. The term "Newburg sand", as used by drillers, has no stratigraphic significance. To devise a precise method for dividing the Lockport would require a detailed investigation beyond the scope of this investigation, and the writer did not attempt to subdivide the Lockport Group in the subsurface.

The Niagaran-Cayugan contact in the subsurface exhibits none of the characteristics associated with an unconformity. Evidence indicative of an unconformity is recorded from outcrops, however; and local areas of unconformity could be expected in the subsurface to the east.

The subdivision of the Salina Group proposed by Landes (1945) for the Michigan basin is practical for use in the subsurface of Ohio. It was of significant help in completing this stratigraphic study of the Salina.

The Greenfield Formation as identified in the outcrop area is continuous throughout Ohio in the subsurface. The formation is correlative with the A-unit carbonate rocks of the Michigan basin, but no salt, as described in Michigan, was observed in the Ohio section.

The C shale-unit is the most easily recognized and extensive interval in the Salina section. This unit can be identified and correlated throughout Michigan, Ontario, and Ohio, and into Pennsylvania and New York.

The various salt layers in the Salina of Ohio are equivalent to corresponding units in Michigan. The two youngest salt beds of the Michigan F unit are not represented in Ohio.

As a group, the Bass Islands can be identified in the subsurface, but the formations described at the outcrop are not recognizable. Difficulty is encountered in differentiating between Helderberg rocks and the Bass Islands Group in eastern Ohio.

The Silurian-Devonian contact is represented by an unconformity, except in eastern Ohio. Truncation and pinch-out of the various Silurian units below the Silurian-Devonian unconformity can be illustrated in northeastern Ohio.

The major basin axis during upper Niagaran and Cayugan time was apparently along a northwest-southeast trend through Cuyahoga, Portage, Mahoning, and Columbiana Counties. Two minor basins, one in Lorain and Ashland Counties, during Lockport-Greenfield time and the other in Lake and Ashtabula Counties, during B-unit time, are also indicated by subsurface information.

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APPENDIX A

SUBSURFACE DATA FROM CONTROL WELLS
(Locations of wells are shown on figure 1. For explanation of well numbers refer to page 3.)

Well Number	Elevation (feet)	Depth of rock units below surface (feet) "Big Lime"	G Unit	F Unit	E Unit	D Unit	C Unit	B Unit	Green-field	Lock-port	Clinton Shale
A1 (D1)	860	--	--	--	--	--	--	--	--	Surf.	237
A2	--	--	--	--	--	--	--	--	--	Surf.	390
A3	641	Surf.	Abs.	15 ?	85 ?	Abs.	155	210	323	514	765
A4 (E2)	--	180	500	565 ?	640 ?	735	745	795	920	1110	1315
A5 (E3)	848	735	1090	1178	1258	1345	1355	1405	1520	1693	1925
A6 (F1)	--	1180	1656	1762	1977	2086	2125	2182	TD	--	--
A7 (G1)	701	1280	1844	1943	2124	2220	2262	2310	2500	2561	2870
B1 (D4)	1007	310	Abs.	488	545	Abs.	636	676	718	905	1113
B2	--	1594	1760	1810	1905	Abs.	2007	2053	2155	2284	2550
B3	1190	1926	2190	2295	2390	Abs.	2474	2536	2640	2773	2960
B4	1072	2113	2273	2380	2484	2590	2608	2658	2764	2893	3078
B5 (E5)	--	2097	2390	2495	2620	2760	2787	2850	2957	3094	3265
B6	--	2330	2710	2835	3004	3152	3190	3254	3366	3477	3698
B7	960	2300	2844	2961	3255	3405	3441	3500	3618	3687	3965
B8 (F3)	--	2375	2916	3039	3332	3469	3506	3557	3680	3743	4058
B9	--	2460	303	3121	3406	3542	3566	3622	3766	3830	4134
B10	1032	2207	2632	2740	2957	3075	3115	3167	3320	3383	3675
B11 (G2)	868	1858	2269	2372	2553	2661	2703	2756	2932	3000	3263
B12	853	1767	2174	2264	2337	2426	2436	2485	2644	2708	2950
B13	839	1692	2060	2146	2214	2310	2318	2357	2480	2537	2780
B14	1240	2110	2469	2558	2632	Abs.	2730	2774	2880	2929	3190
C1 (D6)	1185	1140	Abs.	1246	1353	Abs.	1432	1480	1518	1760	1815
C2	--	1871	2017	2102	2210	Abs.	2294	2353	2390	2490	2723
C3	1096	2327	2517	2620	2735	Abs.	2834	2887	2923	3002	3266
C4	807	2478	2788	2898	3024	Abs.	3130	3195	3226	3308	3544
C5 (E8)	1031	2830	3193	3315	3483	Abs.	3660	3715	3745	3807	4130
C6	--	3152	3553	3703	3910	4102	4117	4175	4283	4341	4575
C7	--	3337	3824	3976	4240	4405	4435	4517	4622	4692	4939
C8 (F5)	1067	2853	3430	3566	3880	4055	4098	4170	4288	4350	4670
C9	1204	3148	3538	3668	3917	4071	4110	4180	4315	4426	4625
C10 (G4)	950	3054	3409	3535	3760	3925	3948	4018	4175	4263	4513
D1 (A1)	860	--	--	--	--	--	--	--	--	Surf.	237
D2	910	Surf.	Abs.	135	210	Abs.	275	330	380	435	600
D3	990	No Samples to 322 feet			322	Abs.	375	418	472	658	839
D4 (B1)	1007	310	Abs.	488	545	Abs.	636	676	718	905	1113
D5	1180	882	Abs.	970	1104	Abs.	1197	1237	1275	1527	1583
D6	1185	1140	Abs.	1246	1353	Abs.	1432	1480	1518	1760	1815
E1	--	Surf.	80	128 ?	200	Abs.	265	310	425	500	885
E2 (A4)	--	180	500	656 ?	690 ?	735	745	795	920	1110	1315
E3 (A5)	848	735	1090	1178	1258	1345	1355	1405	1520	1693	1925
E4	--	1736	2028	2132	2255	2377	2402	2460	2567	2736	2918
E5 (B5)	--	2097	2390	2495	2620	2760	2787	2850	2957	3094	3265
E6	1184	2403	2706	2830	2950	3096	3110	3170	3283	3382	3607
E7	1150	2430	2746	2861	2966	3085	3095	3136	3227	3289	3592
E8 (C5)	1031	2830	3193	3315	3483	Abs.	3660	3715	3745	3807	4130
F1 (A6)	--	1180	1656	1762	1977	2086	2125	2182	TD	--	--
F2	--	2144	2670	2780	3090	3200	3241	3300	3421	3500	3800
F3 (B8)	--	2375	2916	3039	3332	3469	3506	3557	3680	3743	4058
F4	1133	2800	3367	3504	3796	3965	4000	4064	4197	4265	4585
F5 (C8)	1067	2853	3430	3566	3880	4055	4098	4170	4288	4350	4670
G1 (A7)	701	1280	1844	1943	2124	2220	2263	2310	2500	2561	2870
G2 (B11)	868	1858	2268	2372	2553	2661	2703	2756	2932	3000	3263
G3	1141	2648	3010	3111	3306	3416	3467	3525	3662	3746	4072
G4 (C10)	950	3054	3409	3535	3760	3925	3948	4018	4175	4263	4513
1	1398	1060	Abs.	1190	1234	Abs.	1316	1360	1446	1479	2000
2	--	1260	1523	1634	1712	Abs.	1796	1850	1960	2074	2290
3	--	1679	1784?	1864	1959	Abs.	2051	2098	2137	2190	2510
4	--	1655	1805	1880	1985	Abs.	2077	2135	2171	2288	2502
5	--	1662	1810	1886	1992	Abs.	2083	2136	2175	2276	2499
6	--	1800	1978	2075	2181	Abs.	2274	2330	2372	2458	2715
7	--	1848	1980	2075	2187	Abs.	2277	2327	2370	2421	2706
8	1250	1958	2374	2480	2695	2813	2848	2905	3050	3233	3380

Well Number	Elevation (feet)	Depth of rock units below surface (feet) "Big Lime"	G Unit	F Unit	E Unit	D Unit	C Unit	B Unit	Green-field	Lock-port	Clinton Shale
9	1105	1870	2234	2335	2515	2632	2665	2732	2867	3044	3188
10	--	2141	2531	2640	2824	2975	3007	3065	3187	3358?	3520
11	--	1720	1999	2108	2223	2344	2383	2440	2570	2703?	2888
12	--	1950	2235	2337	2449	2585	2616	2661	2790	2942	3105
13	980	1843	2162	2270	2404	2530	2560	2621	2734	2898	3069
14	960	1970	2290	2397	2542	2686	2720	2789	2900	3059	3215
15	950	2093	2441	2553	2721	2850	2890	2954	3069	3213	3390
16	--	2025	2304	2407	2500	2626	2655	2722	2828	2990	3144
17	--	2297	2661	2765	2929	3062	3092	3162	3290	3424	3625
18	1060	2336	2708	2825	3006	3155	3185	3250	3360	3467	3690
19	1087	1868	2132	2236	2325	2426	2450	2507	2610	2784	2924
20	1168	2083	2353	2456	2558	2695	2712	2765	2870	3021	3180
21	1072	2351	2703	2820	2981	3127	3155	3218	3330	3465?	3667
22	1030	2360	2721	2843	3037	3187	3210	3262	3384	3510	3717
23	903	1975	2250	2358	2460	Abs.	2575	2652	2760	2904	3088
24	969	1925	2197	2303	2401	Abs.	2484	2550	2650	2718	2990
25	--	2074	2347	2453	2554	Abs.	2652	2730	2832	2898?	3171
26	1012	2147	2433	2548	2648	Abs.	2733	2792	2888	2933	3240
27	1065	2120	2383	2488	2584	Abs.	2647	2710	2803	2847	3220
28	1100	2070	2295	2397	2502	Abs.	2569	2622	2715	2758	3138
29	--	2354	2664	2776	2881	Abs.	2952	3025	3116	3170	3447
30	1181	2590	2897	3018	3129	Abs.	3246	3310	3400	3458	3722
31	--	2064	2279	2376	2482	Abs.	2570	2610	2690	2742	3106
32	--	2002	2235	2330	2445	Abs.	2531	2575	2665	2752	3034
33	1173	2465	2756	2865	2980	Abs.	3066	3120	3217	3268	3540
34	--	2031	2218	2310	2420	Abs.	2506	2559	2590	2700	2978
35	--	2335	2522	2623	2735	Abs.	2815	2862	2895	2997	3324
36	--	1789	1968	2063	2175	Abs.	2262	2321	2360	2462	2710
37	1122	2113	2287	2364	2475	Abs.	2566	2621	2668	2796	2996
38	856	2307	2522	2630	2753	Abs.	2839	2888	2969	3040	3321
39	--	1758	2244	2357	2602	2744	2763	2824	2943	3018	3286
40	1140	2302	2812	2934	3200	3362	3404	3475	3584	3655	3926
41	992	2183	2621	2735	2937	3097	3132	Td	--	--	--
42	1019	2374	?	2915	3141	3235	3270	3340	3450	3507	3820
43	--	?	3019	3155	3370	3495	3523	3576	3671	3725	4083
44	1201	2724	3216	3345	3600	3750	3777	3837	3943	4000	4307
45	--	2720	3179	3310	3556	3736	3760	3827	3933	3991	4315
46	1115	2766	3246	3380	3648	3798	3847	3914	4023	4085	4360
47	--	2510	2904	3029	3238	3382	3400	3468	3573	3630	3927
48	960	2340	2725	2845	3031	3174	3194	3256	3364	3451	3735
49	--	2624	3042	3165	3417	3572	3598	3654	3752	3798	4132
50	1074	2584	2964	3085	3303	3440	3457	3505	3604	3647	4003
51	1007	2642	3025	3154	3366	3541	3563	3610	3716	3764	4045
52	1069	2854	3267	3409	3626	TD	--	--	--	--	--
53	--	2799	3115	3246	3438	3595	3620	3691	3799	3862	4105
54	--	3035	3437	3583	3785	Abs.	3965	4039	4146	4167	4445
55	1202	2214	2748	2853	3112	3220	3260	3304	3418	3471	3887
56	1135	2335	2891	3014	3290	3436	3460	3515	3670	3742	4018
57	1198	2467	3026	3151	3458	3598	3629	3689	3826	3896	4166
58	1100	2478	3022	3141	3416	3549	3587	3650	3784	3844	4152
59	1087	2430	2979	3108	3400	3560	3598	3665	3790	3856	4127
60	--	2520	3076	3216	3498	3647	3686	3749	3885	3956	4221
61	1180	?	3164	3297	3562	3709	3746	3807	3931	3994	4310
62	1167	2590	3067	3189	3441	3590	3612	3669	3769	3823	4190
63	1257	3620	4149	4305	4573	4780	4803	4873	4988	5032	5352
64	--	1628	1961	2102	2180	Abs.	2278	2324	2465	2540	2782
65	836	1726	2027?	2215	2292	2380	2391	2425	2573	2637	2877
66	895	1824	2210	2299	2378	Abs.	2472	2517	2659	2722	2966
67	852	1722	2093	2214	2350	2450	2493	2550	2710	2778	3040
68	880	1802	2148	2244	2402	2500	2543	2593	2774	2841	3100
69	1018	1989	2330	2422	2578	2685	2725	2775	2960	3027	3285
70	1067	2280	2596	2683	2816	2923	2968	3020	3195	3255	3520
71	1088	2298	2628	2724	2887	2992	3030	3086	3263	3326	3594
72	1078	2012	2445	2545	2732	2848	2882	2932	3101	3170	3447
73	976	1951	2377	2477	2668	2780	2820	2870	3053	3110	3376
74	862	1989	2391	2498	2682	2794	2834	2884	3051	3118	3389
75	1064	2188	2614	2715	2915	3029	3075	3129	3288	3354	3642
76	904	2295	2688	2794	3015	3135	3166	3221	3370	3430	3712
77	1221	3638	4258	4417	4718	4922	4948	5032	5155	5212	5451

APPENDIX B

DESCRIPTIONS OF SAMPLES FROM SELECTED WELLS

(Sample descriptions by J. R. Ulteig)

WELL A3

Ohio Geological Survey Sample 895, State Permit 77.

Sandusky County, Townsend Township, NW¼, Section 33, East Ohio Gas - No. 1 Haff. Elevation 641 feet.

Depth, feet	Descriptions of well samples
	SILURIAN SYSTEM
0-60	No Samples.
?-514	Salina Group
?-85	F Unit?
60-67	Dolomite, 70%, brown (10YR7/2), lithographic with vugs, porosity (5-10%), and colorless to red (10R6/4) gypsum crystals. Limestone, 25%, gray (N6), lithographic, argillaceous (40%). With a few coarse calcite crystals. Shale, 5%, gray (N4), bedded, dolomitic (40%). With a few pyrite crystal inclusions.
67-73	Dolomite, 90%, gray to brown (N6-10YR7/2), lithographic to microcrystalline. With quartz inclusions and rounded sand grains. A few gypsum crystals. Shale, 10%, same as 60-67.
73-78	Dolomite, 95%, same as 67-73. Shale, 5%, same as 60-67.
78-85	Dolomite, 100%, gray to brown (N6-10YR7/2), lithographic to microcrystalline. With quartz and pyrite inclusions, round sand grains, and a few red (10R6/4) gypsum crystals.
85-155	E Unit?
85-90	Dolomite, 100%, same as 78-85, except no pyrite inclusions and only rare sand grains.
90-98	Dolomite, 100%, gray to brown (N6-10YR7/2), lithographic, argillaceous (20%). No pyrite, quartz, or gypsum.
98-104	Dolomite, 95%, brown (10YR7/2), lithographic to microcrystalline. With quartz inclusions, rounded sand grains and red gypsum crystals. Shale, 5%, gray (N4-6), bedded, 20% dolomite cement.
104-107	Dolomite, 100%, gray to brown (N6-10YR7/2), lithographic, argillaceous (40%). No quartz sand.
107-114	Same as 104-107.
114-119	Same as 104-107. With a few gray (N5) shale fragments.
119-125	Dolomite, 100%, brown (10YR7/2), lithographic.
125-132	Same as 119-125.
132-137	Dolomite, 100%, gray to brown (N6-10YR7/2), lithographic. With a few gray (N5) shale fragments. Pinpoint vugs.
137-141	Same as 132-137. Pinpoint vugs, porosity (1-5%). Argillaceous (20%).
141-147	Same as 137-141. With a few chert fragments.
147-155	Dolomite, 50%, brown (10YR7/2), lithographic. With a few anhydrite fragments and pyrite crystal inclusions. Shale, 50%, gray (N6), dolomitic (50%).
155-210	C Unit
155-175	Same as 147-155.
175-180	Shale, 80%, gray (N6), dolomitic (50%). With a few white (N10) anhydrite fragments. Dolomite, 20%, brown (10YR7/2), lithographic, pinpoint vugs.
180-185	Shale, 85%, same as 175-180. Dolomite, 15%, same as 175-180.
185-190	Dolomite, 50%, same as 175-180. Anhydrite, 30%, white (N9-10), very finely crystalline. Dolomite, 20%, gray (N5), lithographic, argillaceous (50%).
190-195	Shale, 90%, gray (N5), dolomitic (50%). Dolomite, 10%, brown, same as 175-180.
195-204	Dolomite, 80%, gray (N5), lithographic, argillaceous (50%). Dolomite, 20%, brown, same as 175-180.
204-209	Shale, 60%, gray (N5), dolomitic (50%). Dolomite, 40%, brown, same as 175-180.
210-323	B Unit
209-215	Dolomite, 60%, gray, same as 195-204. Dolomite, 40%, brown, same as 175-180.
215-220	Shale, 80%, same as 204-209. Dolomite, 20%, brown, same as 175-180.
220-230	Shale, 95%, same as 204-209. Dolomite, 5%, brown, same as 175-180.
230-235	Dolomite, 55%, brown (10YR7/2), lithographic. With pinpoint vugs and a few anhydrite fragments. Shale, 45%, gray-blue (5B4/1), dolomitic (50%).
235-240	Dolomite, 70%, same as 230-235. Dolomite, 30%, gray (N5), lithographic, argillaceous (30%).
240-250	Dolomite, 95%, same as 230-235, lithographic to microcrystalline, anhydrite and pyrite inclusions. Shale, 5%, same as 230-235.
250-261	Same as 240-250.
261-266	Dolomite, 90%, brown (10YR7/2), lithographic, anhydrite, and pyrite inclusions. Dolomite, 10%, gray (N5), lithographic, argillaceous (20%).
266-274	Dolomite, 100%, gray to brown (N4-5YR6/1), lithographic, argillaceous (30%).
274-280	Shale, 50%, gray (N5), dolomitic (50%). Dolomite, 45%, brown (10YR7/2), lithographic. Anhydrite, 5%, brown (5YR6/1), coarse crystals as inclusions in dolomite.
280-290	Dolomite, 90%, gray to brown (N5-10YR7/2), lithographic. With brown (5YR6/1) anhydrite crystal inclusions.
290-298	Dolomite, 100%, same as 280-290.
298-303	Dolomite, 60%, same as 280-290. Shale, 40%, same as 274-280.
303-314	Shale, 100%, gray-green (5GY4/1), dolomitic (50%).
314-322	Same as 303-314.
323-514	Greenfield
322-330	Dolomite, 100%, brown (5YR5-8/1), lithographic, anhydritic (20%).
330-365	Same as 322-330.
365-372	Dolomite, 100%, gray to brown (N5-5YR5/1), lithographic to microcrystalline, sucrosic. With a few gray (N4) shale fragments.
372-380	Same as 365-372. Intercrystalline porosity (1-5%).
380-389	Dolomite, 100%, gray-brown (10YR6/1), lithographic. With a few shale fragments and anhydrite inclusions.
389-422	Same as 380-389.
422-430	Dolomite, 80%, same as 380-389. With anhydrite fragments. Shale, 20%, gray (N5), dolomitic (50%).
430-436	Dolomite, 55%, same as 380-389. Shale, 40%, gray (5B3/1), dolomitic (40%). Anhydrite, 5%, white to brown (N9-10YR7/2), crystalline.
436-443	Dolomite, 90%, gray to brown (N5-5YR6/1), lithographic. With a few pyrite crystal inclusions. Shale, 10%, gray (N4), bedded, 20% dolomite cement.
443-455	Dolomite, 100%, brown (10YR7/2), lithographic to microcrystalline sucrosic. With a few anhydrite fragments.
455-466	Dolomite, 60%, brown (10YR5/2), lithographic. Dolomite, 20%, gray (N4-5), lithographic, argillaceous (50%). Anhydrite, 20%, white (N9), very finely crystalline.
466-476	Same as 455-466.
476-485	Dolomite, 70%, brown, same as 455-466. Dolomite, 15%, gray, same as 455-466. Anhydrite, 15%, white, same as 455-466.
485-490	Dolomite, 70%, brown, same as 455-466. Anhydrite, 20%, white, same as 455-466. Dolomite, 10%, gray, same as 455-466.
490-497	Dolomite, 50%, brown (10YR5-7/2), lithographic. Dolomite, 50%, gray (N4), lithographic, argillaceous (50%).
497-502	Dolomite, 100%, brown (10YR5/2), microcrystalline to finely crystalline, intercrystalline porosity (1-5%), sucrosic. With a few gray (N4) argillaceous dolomite fragments.
502-510	Dolomite, 100%, brown (10YR6/2), lithographic.
510-520	Dolomite, 100%, brown (5YR6/1), lithographic.
514-765	Lockport Group
520-532	Dolomite, 100%, brown (5YR4-6/1), lithographic to microcrystalline.
532-539	Dolomite, 100%, brown (5YR6/1), same as 520-532, sucrosic, intercrystalline porosity (1-5%).

Well A3, Lockport Group (con.)

539-545	Same as 532-539.
545-557	Dolomite, 100%, gray to brown (N6-5YR6/1), same as 532-539.
557-563	Dolomite, 100%, brown (5YR5/1), lithographic.
563-580	Same as 557-563. With gypsum crystals.
580-597	Same as 563-580.
597-602	Dolomite, 100%, gray to brown (N7-5YR6/1), same as 563-580.
602-607	Dolomite, 95%, brown (5YR6/1), lithographic to microcrystalline. Chert, 5%, white (N8).
607-620	Dolomite, 100%, gray (N6-8), microcrystalline to finely crystalline, intercrystalline porosity (1-5%), sucrosic.
620-630	Dolomite, 100%, gray (N8), same as 607-620.
630-655	Same as 620-630.
655-672	Same as 620-630. With gypsum crystals.
672-682	Same as 655-672.
682-692	Dolomite, 100%, gray (N5-8), very fine to medium crystalline, intercrystalline porosity (5-10%), sucrosic. With gypsum crystals.
692-703	Dolomite, 100%, gray (N5-7), microcrystalline to finely crystalline, intercrystalline porosity (5%). With gypsum crystals.
703-712	Dolomite, 100%, gray (N4-6), lithographic to microcrystalline. With pyrite crystal inclusions and gypsum crystals.
712-717	Dolomite, 100%, gray (N4-5), lithographic. With pyrite crystal inclusions and gypsum crystals.
717-722	Missing sample.
722-730	Dolomite, 100%, gray to brown (N5-10YR7/2), lithographic. With pyrite crystal inclusions and green (10G5/2) shale fragments.
730-739	Dolomite, 100%, gray (N3-4), microcrystalline to very finely crystalline, intercrystalline porosity (1-5%), argillaceous (10%). With pyrite crystal inclusions.
739-743	Dolomite, 95%, same as 730-739. Shale, 5%, gray (N4), bedded, 30% dolomite cement.
743-753	Dolomite, 90%, gray (N4-5), lithographic to microcrystalline, argillaceous (30%). Shale, 10%, gray (N4), dolomitic (40%).
753-760	Dolomite, 85%, same as 743-753. Shale, 15%, same as 743-753.
760-768	Dolomite, 100%, gray (N3), lithographic to microcrystalline, argillaceous (40%). With gray (N4) shale fragments.
765- ---	Clinton Group
768-779	Dolomite, 75%, gray to brown (N5-5YR5/1), lithographic, argillaceous (50%). With pyrite crystal inclusions and fossil fragments. Shale, 25%, gray (N5), bedded, dolomitic (30%).

WELL B4

Ohio Geological Survey Sample 914, State Permit 1169.

Wayne County, Plain Township, NW¼, Section 25-E, Kubat - No. 1 Sanger. Elevation: 1074.

Depth, feet	Descriptions of well samples
	DEVONIAN SYSTEM
	Oriskany Sandstone
2167-2187	Sandstone, 60%, quartz, white (N10), fine, subangular, well sorted, calcareous cement (10%). Chert, 40%, white (N10), microfossil inclusions, some chalky fragments.
	SILURIAN SYSTEM
2187-2272	Bass Islands Group
2187-2207	Limestone, 85%, gray-brown (5YR5-7/1), lithographic, dolomitic. Chert, 10%, white (N10), chalky, quartz grain inclusions. Sandstone, 5%, same as 2167-2187.
2207-2233	Limestone, 100%, brown (5YR5-7/1), lithographic to very fine, dolomitic, with a few chert and shale fragments.
2233-2260	Dolomite, 95%, brown (5YR6-7/1), lithographic to very fine. With a few chert and shale fragments. Shale, 5%, gray (N4), bedded, 20% dolomite cement.
2260-2272	Shale, 70%, gray (N4), bedded, 20% dolomite cement. Dolomite, 30%, gray to brown, (N6-5YR6/1), lithographic, argillaceous.
2273-2893	Salina Group
2273-2380	G Unit
2272-2283	Lutite, 50%, brown (5YR6/1), homogeneous, argillaceous (30%), anhydritic (30%), dolomitic (40%), with inclusions of brown anhydrite crystals. Shale, 50%, gray (N4), bedded, 20% dolomite cement.
2283-2292	Lutite, 70%, brown (5YR6/1), homogeneous, argillaceous (40%), anhydritic (40%), dolomitic (20%). Shale, 30%, gray (N4), same as 2272-2283.
2292-2300	Lutite, 90%, brown (5YR6/1), homogeneous, anhydritic (50%), argillaceous (30%), dolomitic (20%). Shale, 10%, gray (N4), same as 2272-2283.
2300-2303	Shale, 50%, red (5R3/2), bedded, 20% dolomite cement. With a few anhydrite fragments. Shale, 50%, gray (N4), same as 2272-2283.
2303-2310	Shale, 40%, red (5R3/2), bedded, 20% dolomite cement. Shale, 30%, gray (N4), same as 2272-2283. Lutite, 30%, brown (5YR6/1), same as 2292-2300.
2310-2319	Anhydrite, 60%, brown (5YR5-7/1), bedded, argillaceous (30%). Shale, 20%, gray (N4), same as 2278-2283. Shale, 20%, red (5R3/2), bedded, 20% dolomite cement.
2319-2326	Anhydrite, 60%, brown (5YR6-8/1), same as 2310-2319. With few chert fragments and quartz grains. Shale, 30%, red (5R4/1), bedded, 20% dolomite cement. Shale, 10%, gray (N4), same as 2272-2283.
2326-2332	Anhydrite, 70%, brown (5YR5/1), bedded, argillaceous (30%). With round pyrite concretions. Shale, 20%, gray (N4), same as 2272-2283. Shale, 10%, red (5R4/1), same as 2319-2326.
2332-2341	Lutite, 100%, brown (10YR6/2), dolomitic (60%), argillaceous (40%). With inclusions of brown anhydrite crystals, a few shale (gray-N4) and anhydrite (white-N10) fragments.
2341-2353	Shale, 75%, gray (N5), bedded, 40% dolomite cement. Lutite, 20%, brown (10YR6/2), same as 2332-2341. Anhydrite, 5%, white (N9 to 5YR8/1), crystalline, microcrystalline to very fine.
2353-2368	Shale, 80%, gray (N5), same as 2341-2353. Lutite, 10%, brown (5YR6/1), same as 2341-2353. Anhydrite, 10%, white (N9-5YR8/1), same as 2341-2353.
2368-2383	Shale, 50%, gray (N4-5), same as 2341-2353. Lutite, 50%, brown (5YR8/1), homogeneous, argillaceous (80%), anhydritic (20%).
2380-2484	F Unit
2383-2399	Lutite, 60%, brown (5YR7-8/1), homogeneous, argillaceous (40%), anhydritic (40%), dolomitic (20%). With a few gray (N4-5) shale fragments. Anhydrite, 40%, brown (N9-5YR8/1), bedded, argillaceous (20%).
2399-2415	Lutite, 90%, brown (5YR6/1), homogeneous, argillaceous (50%), dolomitic (30%), anhydritic (20%). With a few gray (N5) shale fragments. Anhydrite, 10%, brown (5YR8/1), bedded, argillaceous (20%).
2415-2432	Dolomite, 70%, brown (10YR6/2), lithographic, argillaceous (20%). With a few gray (N5) shale fragments. Anhydrite, 30%, white (N7-9), microcrystalline to very fine, argillaceous (20%).
2432-2450	Dolomite, 90%, brown (5YR5-7/1), same as 2415-2432. Anhydrite, 10%, white (N7-9), same as 2415-2432.
2450-2465	Dolomite, 90%, brown (5YR5-8/1), same as 2415-2432. With a few pyrite crystal inclusions. Anhydrite, 10%, white (N7-9), same as 2415-2432.
2465-2484	Anhydrite, 60%, white (N7-9), bedded, argillaceous (20% Dolomite, 40%, brown (5YR5-8/1), lithographic, argillaceous (30%).
2484-2590	E Unit
2484-2498	Dolomite, 50%, brown (5YR6/1), lithographic, argillaceous (20%). Shale, 40%, gray (N5-5G5/1), bedded, 20% dolomite cement. Anhydrite, 10%, white (N9), microcrystalline to very fine.
2498-2513	Dolomite, 60%, brown (5YR4-6/1), lithographic, argillaceous (30%). With inclusions of brown anhydrite crystals. Anhydrite, 35%, gray to brown (N9-5YR8/1), bedded, crystalline, argillaceous and dolomitic (30%). Shale, 5%, gray (N5), bedded, 20% dolomite cement.
2513-2521	Dolomite, 70%, brown (5YR4-6/1), same as 2498-2513. Anhydrite, 25%, white (N9), same as 2498-2513. Shale, 5%, gray (N5), same as 2498-2513.

Well B4, Salina Group, E Unit (con.)

2521-2540	Dolomite, 100%, brown (5YR4-6/1), same as 2498-2513. With a few white (N9) anhydrite fragments.
2540-2556	Dolomite, 80%, brown (10YR6/2), lithographic, argillaceous (50%). With a few gray (N5) shale fragments.
	Anhydrite, 20%, brown (5YR9/1), bedded.
2556-2576	Dolomite, 80%, brown (10YR6/2), same as 2540-2556.
	Anhydrite, 20%, brown (5YR9/1), same as 2540-2556.
2576-2592	Shale, 100%, gray to brown (N6-5YR6/1), dolomitic (50%). With a few brown (5YR6/1), anhydrite and gray (N3) shale fragments.
2590-2608	D Unit
2592-2612	Shale, 100%, brown (10YR6/2), same as 2576-2592, dolomitic (40%).
2608-2658	C Unit
2612-2628	Shale, 90%, brown (5YR6/1), dolomitic (20%). With a few gray-green (5G5/1) shale fragments.
	Anhydrite, 10%, white (5YR8/1), microcrystalline to very fine.
2628-2643	Shale, 80%, green (5G4-5/1), bedded, 20% dolomite cement. With a few white (N9) anhydrite fragments.
	Shale, 20%, brown (5YR6/1), dolomitic (40%).
2643-2660	Shale, 80%, green (5G4/1), same as 2628-2643.
	Shale, 20%, brown (5YR6/1), anhydritic (40%).
2658-2764	B Unit
2660-2674	Shale, 60%, green (5G4-5/1), bedded, 20% dolomite cement.
	Lutite, 40%, brown (5YR4-7/1), homogeneous, anhydritic (50%), dolomitic (30%), argillaceous (20%).
2674-2689	Lutite, 80%, gray to brown (N6-5YR6/1), homogeneous, argillaceous (40%), dolomitic (30%), anhydritic (30%).
	Shale, 20%, green (5G5/1), bedded, 20% dolomite cement.
2680-2709	Lutite, 40%, brown (5YR5/1), homogeneous, dolomitic (40%), anhydritic (30%), argillaceous (30%).
	Shale, 40%, gray (N5-5YR6/1), bedded, 30% dolomite cement.
	Anhydrite, 20%, white (N9-5YR8/1), microcrystalline to very fine.
2709-2720	Dolomite, 60%, brown (5YR5-6/1), microcrystalline, argillaceous (20%).
	Anhydrite, 20%, white (N9), microcrystalline to very fine.
	Shale, 20%, gray (N4-6), bedded, 20% dolomite cement.
2720-2736	Dolomite, 80%, brown (5YR5-7/1), lithographic, argillaceous (30%).
	Anhydrite, 10%, white (N9), same as 2709-2720.
	Shale, 10%, gray (N4), dolomitic (40%).
2736-2756	Lutite, 90%, brown (5YR5-8/1), homogeneous, dolomitic (50%), argillaceous (30%), anhydritic (20%).
	Shale, 10%, gray (N4), bedded, 20% dolomite cement.
2756-2771	Lutite, 80%, brown (5YR5-8/1), same as 2736-2756.
	Shale, 10%, gray (N4-5), bedded, 20% dolomitic cement.
	Anhydrite, 10%, brown (5YR6-8/1), microcrystalline to very fine.
2764-2893	Greenfield
2771-2782	Dolomite, 100%, brown (5YR3-6/1), lithographic, argillaceous (20%), darkest fragments are dolomitic shale (10%). Very few white (N9) anhydrite fragments.
2782-2796	Dolomite, 100%, brown (5YR3-6/1), same as 2771-2782. With a few white (N9) anhydrite fragments.
2796-2804	Dolomite, 100%, brown (5YR3-6/1), lithographic to very fine, argillaceous (20%), intercrystalline porosity (1-5%).
2804-2816	Dolomite, 60%, gray to brown (N4-5YR5/1), lithographic, argillaceous (40%).
	Shale, 30%, gray (N4-5), bedded, dolomitic (40%).
	Anhydrite, 10%, white (N9), microcrystalline to very fine.
2816-2831	Dolomite, 100%, brown (10YR6-8/1), microcrystalline to very fine, sucrosic, intercrystalline porosity (5-10%). With a few gray (N4-5) shale and white (N9) anhydrite fragments.
2831-2850	Anhydrite, 90%, white (N10), microcrystalline to very fine.
	Dolomite, 5%, brown (5YR5/1), same as 2816-2831.
	Shale, 5%, gray (N5), same as 2804-2816.
2850-2866	Lutite, 50%, brown (5YR6/1), homogeneous, dolomitic (50%), anhydritic (30%), argillaceous (20%).
	Anhydrite, 40%, brown (5YR7-8/1), very finely crystalline.
	Shale, 10%, gray (N4-5), same as 2804-2816.
2866-2880	Dolomite, 80%, brown (5YR5-6/1), microcrystalline, argillaceous (10%), with a few white (N9) anhydrite fragments.
	Shale, 20%, gray (N4-5), bedded, 30% dolomite cement.
2880-2892	Shale, 60%, gray (N4-5), bedded, dolomitic (40%).
	Dolomite, 40%, brown (5YR6/1), microcrystalline, argillaceous (20%).
2893-3078	Lockport Group
2892-2902	Dolomite, 90%, brown (5YR5/1), microcrystalline, argillaceous (10%).
	Shale, 10%, gray (N4-5), same as 2880-2892.
2902-2921	Dolomite, 100%, brown (5YR4-6/1), microcrystalline, argillaceous (10%).
2921-2955	Dolomite, 100%, brown (5YR4-6/1), microcrystalline.
2955-2959	Dolomite, 100%, brown (10YR6/2), microcrystalline to very fine, intercrystalline porosity (1-5%).
2959-2983	Dolomite, 100%, brown (10YR5-7/2), microcrystalline.
2983-3010	Dolomite, 100%, brown (5YR7-8/1), very fine to finely crystalline, intercrystalline porosity (5-10%). With a few inclusions of pyrite crystals.
3010-3021	Dolomite, 100%, gray to brown (N7-5YR8/1), same as 2983-3010.
3021-3038	Dolomite, 60%, gray to brown (N7-5YR8/1), same as 2983-3010.
	Shale, 40%, gray (N4-5), dolomitic (50%).
3038-3050	Dolomite, 90%, gray (N8-9), microcrystalline to very fine, intercrystalline porosity (1-5%).
	Shale, 10%, gray (N5-8), dolomitic (50%).
3050-3065	Shale, 90%, gray (N4), bedded, 30% dolomite cement.
	Dolomite, 10%, gray (N8-9), same as 3038-3050.
3065-3075	Shale, 60%, gray (N4), same as 3050-3065.
	Dolomite, 40%, brown (5YR8/1), very fine to finely crystalline, argillaceous.
3078- ---	Clinton Group
3075-3087	Shale, 100%, gray (N3-4), bedded, 20% dolomite cement. With some gray to brown (N7-5YR8/1) dolomite fragments.

WELL B7

Ohio Geological Survey Sample 721, State Permit 40.

Portage County, Brimfield Township, Lot 22, East Ohio Gas No. 1 Heichel. Elevation 1960 feet.

Depth, feet	Descriptions of well samples
	DEVONIAN SYSTEM
--- -2634	Onondaga Limestone
2624-2634	Limestone, 60%, gray-brown (5YR7/1), lithographic. With gray (N4) shale fragments.
	Chert, 40%, gray to brown (N7-5YR8/1).
	SILURIAN SYSTEM
2634-2844	Bass Islands Group
2634-2650	Limestone, 100%, gray to brown (N4-5YR7/1), lithographic, argillaceous (30%).
2650-2666	Same as 2634-2650.
2666-2680	Limestone, 100%, gray to brown (N5-5YR8/1), lithographic, argillaceous (40%), with gray (N4) shale fragments.
2680-2693	Limestone, 100%, brown (5YR5-7/1), same as 2666-2680.
2693-2718	Same as 2680-2693.
2718-2730	Same as 2680-2693.
2730-2742	Same as 2680-2693. With a few chert fragments.
2742-2752	Same as 2730-2742.
2752-2771	Limestone, 100%, gray-brown (5YR5-7/1), lithographic, argillaceous (30%). With brown (10YR5/2) anhydrite crystal inclusions and gray (N4) shale fragments.
2771-2786	Same as 2752-2771. With a few white (N9) crystalline anhydrite fragments.
2786-2811	Same as 2771-2786, dolomitic.
2811-2826	Dolomitic, 95%, brown (5YR4-8/1), lithographic, calcareous, argillaceous (30%). With a few gray (N4) shale fragments.
	Anhydrite, 5%, brown (10YR8/2), crystalline.
2826-2835	Lutite, 80%, brown (5YR4-8/1), homogeneous, dolomitic (40%), anhydritic (40%), argillaceous (20%).
	Anhydrite, 20%, same as 2811-2826.
2835-2846	Lutite, 50%, same as 2826-2835.
	Anhydrite, 50%, same as 2811-2826.

Well B7 (con.)

2844-3965 Salina Group

2844-2961 G Unit

2846-2864 Anhydrite, 100%, brown (10YR4/2), bedded, dolomitic (30%).
2864-2894 Same as 2846-2864.
2894-2912 Shale, 100%, gray (N4-5), bedded, anhydritic (50%).
2912-2928 Shale, 100%, gray (N5), bedded, anhydritic (30%).
2928-2937 Lutite, 100%, gray (N5), homogeneous, argillaceous (60%), anhydritic (20%), dolomitic (20%).
2937-2959 Same as 2928-2937.

2961-3255 F Unit

2959-2975 Lutite, 50%, gray to brown (N5-5YR6/1), homogeneous, argillaceous (50%), anhydritic (30%), dolomitic (20%).
Salt, 40%, white (N10), crystalline.
Anhydrite, 10%, brown (10YR8/2), crystalline.
2975-2993 Lutite, 70%, same as 2959-2975.
Salt, 30%, white (N10), crystalline.
2993-3013 Same as 2975-2993.
3013-3030 Same as 2975-2993.
3030-3042 Lutite, 90%, same as 2959-2975.
Salt, 10%, white (N10), crystalline.
3042-3057 Lutite, 100%, brown (10YR5/2), homogeneous, dolomitic (40%), argillaceous (30%), anhydritic (30%).
3057-3073 Same as 3042-3057.
3073-3086 Same as 3042-3057.
3086-3096 Same as 3042-3057.
3096-3117 Missing sample.
3117-3137 Salt, 90%, white (10YR9/2), crystalline.
Shale, 10%, gray to brown (N4-5YR6/1), bedded, 20% dolomite cement.
3137-3155 Lutite, 60%, brown (5YR6-7/1), homogeneous, dolomitic (40%), argillaceous (30%), anhydritic (30%).
Anhydrite, 25%, white (N10), very finely crystalline.
Shale, 10%, gray (N4), bedded, 20% dolomite cement.
Salt, 5%, white (N10), crystalline.
3155-3175 Missing sample.
3175-3197 Salt, 80%, white (N10), crystalline.
Shale, 20%, brown (5YR6/1), dolomitic (30%).
3197-3224 Salt, 50%, white (N10), crystalline.
Shale, 50%, brown (5YR6/1), dolomitic (30%).
3224-3242 Salt, 70%, white (N10), crystalline.
Shale, 25%, brown (5YR6/1), dolomitic (40%).
Shale, 5%, gray (N4), 20% dolomite cement.
3242-3252 Lutite, 80%, brown (5YR6/1), homogeneous, argillaceous (40%), dolomitic (30%), anhydritic (30%).
Shale, 20%, gray (N4), 20% dolomite cement.

3255-3404 E Unit

3252-3264 Lutite, 100%, gray to brown (N4-5YR6/1), same as 3242-3252.
3264-3279 Lutite, 50%, same as 3252-3264.
Anhydrite, 50%, brown (10YR8/2), crystalline.
3279-3299 Lutite, 90%, brown (5YR6/1), homogeneous, argillaceous (40%), anhydritic (40%), dolomitic (20%).
Salt, 10%, white (N10), crystalline.
3299-3322 Lutite, 70%, same as 3279-3299.
Salt, 30%, same as 3279-3299.
3322-3343 Lutite, 100%, brown (10YR6/2), same as 3279-3299.
3343-3363 Same as 3322-3343.
3363-3394 Same as 3322-3343. With a few gray (N4) shale fragments.

3404-3441 D Unit

3394-3411 Lutite, 65%, same as 3322-3343.
Salt, 30%, white (N10), crystalline.
Shale, 5%, gray (N4), bedded, 20% dolomite cement.
3411-3428 Lutite, 50%, same as 3322-3343.
Shale, 40%, green (5G6/1), bedded, 20% dolomite cement.
Salt, 10%, white (N10), crystalline.
3428-3438 Shale, 50%, green, same as 3411-3428.
Lutite, 40%, brown, same as 3322-3343.
Salt, 10%, white (N9), crystalline.

3441-3500 C Unit

3438-3455 Lutite, 80%, brown, same as 3322-3343.
Shale, 10%, green, same as 3411-3428.
Salt, 10%, white (N9), crystalline.
3455-3475 Shale, 70%, green (5YR6/1), bedded, anhydritic (30%).
Lutite, 30%, same as 3322-3343.
3475-3500 Shale, 100%, gray to brown (N4-5YR6/1), anhydritic (30%).

3500-3618 B Unit

3500-3516 Same as 3475-3500.
3516-3530 Same as 3475-3500.
3530-3546 Shale, 90%, brown (5YR6/1), same as 3475-3500.
Anhydrite, 10%, white (N10), very finely crystalline.
3546-3564 Lutite, 90%, brown (5YR6/1), homogeneous, dolomitic (40%), argillaceous (30%), anhydritic (30%).
Anhydrite, 10%, white (N9), very finely crystalline.
3564-3578 Lutite, 100%, brown (5YR4-5/1), same as 3546-3564.
3578-3596 Same as 3564-3578.
3596-3611 Lutite, 100%, brown (5YR5-6/1), homogeneous, argillaceous (40%), dolomitic (30%), anhydritic (30%).
3611-3623 Lutite, 100%, gray to brown (N4-5YR6/1), same as 3596-3611.

3618-3687 Greenfield

3623-3637 Same as 3611-3623.
3637-3651 Dolomite, 100%, brown (5YR3-5/1), microcrystalline, argillaceous (30%), anhydritic (10%). With a few gray (N4) shale fragments.
3651-3666 Dolomite, 90%, brown (5YR6/1), lithographic, anhydritic (30%), argillaceous (10%). With a few gray (N4) shale fragments.
Anhydrite, 10%, white (N10), very finely crystalline.
3666-3679 Dolomite, 60%, same as 3651-3666.
Anhydrite, 40%, same as 3651-3666.

3687-3965 Lockport Group

3679-3695 Dolomite, 100%, brown (10YR4/2), very finely crystalline, intercrystalline porosity (5-10%). With a few gray (N4) shale and white (N10) crystalline anhydrite fragments.
3695-3709 Dolomite, 100%, brown (10YR4-6/2), same as 3679-3695.
3709-3715 Same as 3695-3709.
3715-3725 Dolomite, 100%, brown (10YR6/2), very finely crystalline, intercrystalline porosity (10-20%). Cuttings resemble sand. ("Newburg")
3725-3732 Dolomite, 90%, same as 3715-3725.
Shale, 10%, gray (N4), bedded, 20% dolomite cement.
3732-3743 Dolomite, 95%, same as 3715-3725. With gypsum crystals.
Shale, 5%, same as 3725-3732.
3743-3752 Same as 3732-3743.
3752-3758 Same as 3732-3743.
3758-3765 Dolomite, 100%, brown (10YR6/2), lithographic, argillaceous (20%). With a few gray (N4) shale fragments.
3765-3770 Dolomite, 100%, brown (10YR6/2), microcrystalline, same as 3758-3763.
3770-3778 Same as 3765-3770.
3778-3785 Dolomite, 100%, brown (10YR6/2), microcrystalline to very finely crystalline, intercrystalline porosity (1-5%).
3785-3791 Dolomite, 90%, brown (10YR6/2), microcrystalline.
Shale, 10%, green (5G6/1), bedded, 20% dolomite cement.
3791-3798 Dolomite, 100%, same as 3785-3791. With a few shale fragments and gypsum crystals.
3798-3804 Dolomite, 100%, brown (10YR6/2), microcrystalline to very finely crystalline, intercrystalline porosity (1-5%). With a few gray (N4) shale fragments.
3804-3810 Dolomite, 70%, same as 3798-3804.
Quartz, 20%, white (N10-10YR9/2), angular. (Glass?)
Shale, 10%, gray (N4), bedded, 20% dolomite cement.
3810-3819 Dolomite, 90%, gray to brown (N6-5YR6/1), microcrystalline, argillaceous (10%). With a few gray (N4) shale fragments.
Quartz, 10%, white (N10-10YR9/2), angular. (Glass?)
3819-3825 Dolomite, 100%, brown (10YR6/2), microcrystalline, argillaceous (10%). With a few quartz and shale fragments.
3825-3829 Same as 3819-3825, except no quartz.
3829-3836 Same as 3825-3829. With a few gypsum crystals.
3836-3844 Same as 3829-3836.
3844-3850 Dolomite, 100%, brown (10YR6/2), microcrystalline. With a few gray (N4) shale fragments.
3850-3858 Same as 3844-3850.
3858-3871 Same as 3844-3850.
3871-3184 Dolomite, 100%, brown (10YR5-7/2), microcrystalline to very finely crystalline, intercrystalline porosity (1-5%). With a few gray (N4) shale fragments and gypsum crystals.
3884-3890 Dolomite, 95%, same as 3871-3877.
Chert, 5%, white (N10), chalky.
3890-3896 Dolomite, 100%, brown (5YR5-7/1), microcrystalline. With a few gray (N4) shale and chert fragments and gypsum crystals.
3896-3904 Dolomite, 100%, brown (10YR6/2), microcrystalline to very fine crystalline, intercrystalline porosity (1-5%). With a few gray (N4) shale fragments and gypsum crystals.

Well B7, Lockport Group (con.)

3904-3912	Same as 3896-3904. With a few chert fragments.
3912-3918	Dolomite, 60%, brown (10YR6/2), microcrystalline. With a few gray (N4) shale fragments.
	Chert, 40%, brown (10YR8/2), angular.
3918-3925	Dolomite, 70%, same as 3912-3918.
	Chert, 30%, same as 3912-3918.
3925-3934	Dolomite, 70%, same as 3912-18, microcrystalline to very finely crystalline, intercrystalline porosity (1-5%).
	Chert, 30%, same as 3912-3918.
3934-3941	Same as 3912-3918.
3941-3951	Dolomite, 60%, gray to brown (N6-5YR6/1), lithographic, argillaceous (20%).
	Shale, 40%, gray (N4), dolomitic (40%).
3951-3961	Same as 3941-3951.
3965- ---	Clinton Group
3961-3968	Dolomite, 80%, gray (N6-5YR6/1), lithographic, argillaceous (40%).
	Shale, 20%, gray (N4), bedded, 20% dolomite cement.
3968-3977	Dolomite, 60%, gray (N6), lithographic, argillaceous (50%).
	Shale, 40%, gray (N4), bedded, 20% dolomite cement.

WELL B12

Ohio Geological Survey Sample 818, State Permit No. 73.

Ashtabula County, Monroe Township, Lot 1, McConnell - No. 1 Brydle. Elevation: 860 feet.

Depth, feet	Descriptions of well samples
	DEVONIAN SYSTEM
	Oriskany Sandstone
2080-2090	Sandstone, 100%, white (N10), fine, quartz, well sorted, calcareous cement.
2090-2110	Missing sample.
	SILURIAN SYSTEM
2103-2174	Bass Islands Group
2110-2120	Dolomite, 60%, brown (10YR5/2), microcrystalline to very fine.
	Dolomite, 35%, gray (N7), lithographic, argillaceous (40%).
	Shale, 5%, gray (N4), bedded, 20% dolomite cement.
2120-2130	Dolomite, 45%, brown (10YR5/2), same as 2110-2120.
	Dolomite, 45%, gray (N7), same as 2110-2120.
	Shale, 10%, gray (N4), same as 2110-2120.
2130-2140	Dolomite, 60%, gray (N7), same as 2110-2120.
	Dolomite, 30%, brown (10YR5/2), same as 2110-2120.
	Shale, 10%, gray (N4), same as 2110-2120.
2140-2150	Dolomite, 100%, gray (N7-5YR7/1), lithographic, argillaceous (40%). With a few brown (10YR5/2) dolomite and gray (N4) shale fragments.
2150-2160	Dolomite, 85%, brown (10YR6-7/2), microcrystalline to very fine.
	Dolomite, 10%, gray (5YR7/1), lithographic, argillaceous (40%).
	Shale, 5%, black (N2), dolomitic (50%).
2160-2170	Dolomite, 100%, gray (5YR5-6/1), microcrystalline, argillaceous (10%). With a few black (N2) shale fragments.
2174-2708	Salina Group
2174-2264	G Unit
2170-2180	Dolomite, 90%, gray (5YR5-6/1), same as 2160-2170.
	Shale, 10%, gray (N3-4), dolomitic (50%).
2180-2190	Shale, 70%, gray (N3-4), dolomitic (50%).
	Anhydrite, 30%, white (N10), crystalline, very fine. Some brown (5YR6/2) anhydrite crystals.
2190-2200	Shale, 60%, gray (N3-4), dolomitic (50%).
	Anhydrite, 40%, white (N10), same as 2180-2190.
2200-2210	Anhydrite, 50%, white (N10), same as 2180-2190.
	Dolomite, 30%, brown (10YR4-6/2), microcrystalline.
	Shale, 20%, gray (N3-4), dolomitic (50%).
2210-2220	Lutite, 100%, gray (N4), bedded, homogeneous, dolomitic (30%), argillaceous (40%), anhydritic (30%). With a few white (N10) anhydrite crystals and brown (10YR4-6/2) dolomite fragments.
2220-2230	Lutite, 70%, gray (N4), same as 2210-2220.
	Dolomite, 25%, brown (5YR4-6/1), microcrystalline.
	Anhydrite, 5%, white (N9-10), crystalline, very fine.
2230-2240	Lutite, 70%, gray (N4-5), same as 2210-2220.
	Dolomite, 20%, brown (5YR4-6/1), same as 2220-2230.
	Anhydrite, 10%, white (N9-10), same as 2220-2230.
2240-2250	Lutite, 95%, gray (N4), same as 2210-2220.
	Anhydrite, 5%, white (N9-10), same as 2220-2230.
2250-2260	Same as 2240-2250.
2264-2337	F Unit
2260-2270	Lutite, 90%, gray to brown (N4-5YR4/1), homogeneous, dolomitic (40%), argillaceous (40%), anhydritic (20%).
	Anhydrite, 10%, white (N9-10), crystalline, very fine.
2270-2280	Lutite, 85%, gray to brown (N4-5YR4/1), same as 2260-2270.
	Anhydrite, 15%, white (N9-10), same as 2260-2270.
2280-2290	Lutite, 90%, gray to brown (N4-5YR4/1), same as 2260-2270.
	Anhydrite, 10%, white (N9-10), same as 2260-2270. With a few brown (5YR5/2) anhydrite fragments.
2290-2300	Lutite, 80%, brown (10YR6/2), homogeneous, dolomitic (40%), anhydritic (40%), argillaceous (20%). With inclusions of brown (10YR4/2) anhydrite crystals.
	Anhydrite, 20%, white to brown (N9-10YR4/2), crystalline, very fine to coarse.
2300-2310	Lutite, 80%, gray to brown (N4-5YR5/2), homogeneous, dolomitic (50%), argillaceous (30%), anhydritic (20%).
	Anhydrite, 20%, white to brown (N9-10YR4/2), same as 2290-2300.
2310-2320	Dolomite, 95%, brown (10YR5/2), lithographic, argillaceous (30%), anhydritic (10%). With a few gray (N4) shale fragments.
	Anhydrite, 5%, white (N9), very finely crystalline.
2320-2330	Same as 2310-2320.
2330-2340	Dolomite, 50%, brown (10YR5/2), same as 2310-2320.
	Dolomite, 45%, gray (N3-4), lithographic, argillaceous (50%).
	Anhydrite, 5%, white (N9), same as 2310-2320.
2337-2426	E Unit
2340-2350	Dolomite, 70%, brown (10YR5/2), lithographic, argillaceous (10%).
	Dolomite, 25%, gray (5Y5/1), lithographic, argillaceous (20%).
	Anhydrite, 5%, gray to brown (N9-10YR4/2), very fine to coarsely crystalline.
2350-2360	Dolomite, 95%, gray (5Y5/1), lithographic, argillaceous (20%), anhydritic (10%).
	Anhydrite, 5%, white (N9), crystalline.
2360-2370	Lutite, 100%, gray to brown (5Y5/1-10YR5/2), lithographic to microcrystalline, homogeneous, dolomitic (50%), anhydritic (40%), argillaceous (10%).
2370-2380	Same as 2360-2370.
2380-2390	Lutite, 100%, brown (5YR5/1), lithographic to microcrystalline, homogeneous, dolomitic (40%), anhydritic (30%), argillaceous (30%). With a few gray (N4) shale fragments.
2390-2400	Same as 2380-2390.
2400-2410	Lutite, 100%, brown (10YR6/2), lithographic, same as 2380-2390. With a few brown (10YR4/2) anhydrite crystals.
2410-2420	Same as 2400-2410.
2420-2430	Lutite, 90%, gray to brown (N6-5YR6/1), lithographic, homogeneous, dolomitic (35%), anhydritic (35%), argillaceous (30%). With a few pyrite crystal inclusions.
	Anhydrite, 10%, brown (10YR5/2), coarse crystals.
2426-2436	D Unit
2430-2440	Dolomite, 60%, brown (10YR6/2), lithographic, argillaceous (40%), pinpoint vugs (salt cast?).
	Anhydrite, 40%, gray (N4-5YR4/1), bedded, dolomitic (40%). With white (N9) crystalline anhydrite fragments.
2436-2485	C Unit
2440-2450	Dolomite, 90%, brown (10YR6/2), same as 2430-2440.
	Anhydrite, 10%, gray (N4-5YR4/1), same as 2430-2440, argillaceous (50%).
2450-2460	Dolomite, 50%, brown (10YR5/2), lithographic, argillaceous (40%). With a few white (N9) crystalline anhydrite fragments.
	Shale, 50%, green (5GY5/1), bedded, dolomitic (50%).
2460-2470	Shale, 95%, brown to green (10YR5/2-5GY5/1), bedded, dolomitic (50%).
	Anhydrite, 5%, white to brown (N9-10YR5/2), very fine to coarsely crystalline.
2470-2480	Shale, 100%, green (5G6/1), bedded, dolomitic (50%).
2480-2490	Shale, 50%, green (5G6/1), same as 2470-80.
	Anhydrite, 50%, brown (5YR5/1), bedded, dolomitic (40%).

Well B12, Salina Group (con.)

2485-2644	B Unit
2490-2500	Shale, 60%, green (5G6/1), same as 2470-2480. Anhydrite, 40%, white to brown (N9-5YR5/1), same as 2480-2490.
2500-2510	Shale, 80%, green (5G6/1), bedded, dolomitic (40%). With a few pyrite crystal inclusions. Dolomite, 10%, brown (10YR5/2), lithographic, anhydritic (40%). Anhydrite, 10%, brown (5YR5/1), bedded, dolomitic (40%).
2510-2520	Lutite, 95%, brown (5YR4-5/1), lithographic, homogeneous, dolomitic (40%), anhydritic (40%), argillaceous (20%). With a few white (N9) crystalline hydrite fragments. Shale, 5%, green (5G6/1), same as 2500-2510.
2520-2530	Lutite, 100%, brown (5YR5/1), homogeneous, anhydritic (50%), dolomitic (30%), argillaceous (20%).
2530-2540	Lutite, 100%, gray to brown (N5-10YR6/2), homogeneous, anhydritic (50%), dolomitic (30%), argillaceous (20%). With pinpoint vugs and a few pyrite crystal inclustions.
2540-2550	Lutite, 40%, gray to brown (N5-10YR6/2), same as 2530-2540. Shale, 40%, green (5GY6/1), bedded, dolomitic (50%). Anhydrite, 20%, brown (10YR6/2), dolomitic (40%).
2550-2560	Lutite, 50%, brown (10YR6/2), homogeneous, dolomitic (40%), anhydritic (30%), argillaceous (30%). Shale, 50%, green (5GY6/1), bedded, dolomitic (40%). With a few pyrite crystal inclusions.
2560-2570	Missing sample.
2570-2580	Lutite, 100%, brown (10YR6/2), same as 2550-2560.
2580-2590	Same as 2570-2580.
2590-2600	Same as 2570-2580
2600-2610	Lutite, 95%, brown (10YR6/2), same as 2570-2580. Anhydrite, 5%, white (N9), very finely crystalline.
2610-2620	Lutite, 90%, brown (10YR6/2), same as 2570-2580. Anhydrite, 10%, white (N9), same as 2600-2610.
2620-2630	Lutite, 95%, brown (10YR6/2), same as 2570-2580. Anhydrite, 5%, white (N9), same as 2600-2610.
2630-2640	Same as 2620-2630. With a few chert fragments.
2644-2708	Greenfield
2640-2650	Lutite, 60%, brown (10YR5/2), homogeneous, dolomitic (60%), anhydritic (20%), argillaceous (20%). Anhydrite, 40%, brown (10YR2-4/2), dolomitic (40%).
2650-2660	Dolomite, 100%, brown (10YR2-5/2), lithographic, anhydritic (50%). With a few pyrite crystal inclusions and gray (N5) shale fragments.
2660-2670	Dolomite, 100%, brown (10YR2-6/2), same as 2650-2660.
2670-2680	Same as 2660-2670.
2680-2690	Dolomite, 100%, brown (10YR3/2), very finely crystalline. With a few white (N9) crystalline anhydrite fragments.
2690-2700	Same as 2680-2690. With a few gray (N4) shale fragments.
2700-2710	Anhydrite, 60%, brown (10YR3/2), dolomitic (50%). Shale, 30%, gray (N3), bedded, 20% dolomite cement. Shale, 10%, green (5GY5/1).
2708-2950	Lockport Group
2710-2720	Dolomite, 90%, brown (10YR4/2), lithographic to microcrystalline. With a few white (N9) crystalline anhydrite fragments. Shale, 10%, gray (N3), dolomitic (50%).
2720-2730	Dolomite, 100%, gray to brown (N6-10YR4/2), same as 2710-2720. With a few gray (N3) shale fragments.
2730-2740	Dolomite, 100%, gray to brown (N6-10YR4-6/2), same as 2720-2730.
2740-2750	Dolomite, 100%, brown (10YR4-6/2), same as 2720-2730.
2750-2760	Missing sample.
2760-2770	Same as 2740-2750. With a few gypsum crystals.
2770-2780	Dolomite, 100%, brown (10YR5/2), same as 2760-2770.
2780-2790	Dolomite, 100%, gray to brown (N4-10YR5/2), lithographic to very fine, same as 2760-2770.
2790-2800	Dolomite, 100%, gray to brown (N4-10YR5/2), lithographic to microcrystalline. With a few black (N3) shale fragments and rare gypsum crystals.
2800-2810	Same as 2790-2800.
2810-2820	Dolomite, 100%, gray to brown (N4-10YR3-6/2), same as 2790-2800.
2820-2830	Dolomite, 100%, gray to brown (N5-10YR5-6/2), microcrystalline. With a few gypsum crystals.
2830-2840	Same as 2820-2830.
2840-2850	Dolomite, 100%, brown (5YR3-6/2), microcrystalline to very fine. With a few gypsum crystals and gray (N4) shale fragments.
2850-2860	Same as 2840-2850, microcrystalline to finely crystalline, intercrystalline porosity (1-5%).
2860-2870	Same as 2850-2860.
2870-2880	Dolomite, 100%, brown (5YR3-7/2), microcrystalline to very fine, (porosity?).
2880-2890	Same as 2870-2880. With a few gypsum crystals.
2890-2900	Same as 2880-2890. With a few chalky (N10) chert fragments.
2900-2910	Dolomite, 100%, brown (10YR5/2), microcrystalline to very fine, intercrystalline porosity (1-5%). With a few gypsum crystals.
2910-2920	Dolomite, 100%, brown (10YR5/2), lithographic to microcrystalline, argillaceous (10%). With a few gypsum crystals and pyrite crystal inclusions.
2920-2930	Dolomite, 100%, brown (10YR5/1), same as 2910-2920. With a few gray (N3-4) shale fragments.
2930-2940	Same as 2920-2930.
2940-2950	Dolomite, 100%, gray to brown (N6-5YR6/1), lithographic to microcrystalline. With a few gypsum crystals and gray (N3-4) shale fragments.
2950- ---	Clinton Group
2950-2960	Missing sample.
2960-2970	Shale, 100%, gray to brown (N4-5YR6/1), bedded, dolomitic (40%). With a few pyrite crystal inclusions.

WELL C1-D6

Ohio Geological Survey Sample 855, State Permit 1803.

Licking County, Hartford Township, Lot 2, Patten - No. 1 Martin. Elevation: 1185 feet.

Depth, feet	Descriptions of well samples
	DEVONIAN SYSTEM
	Onondaga Limestone
1221-1236	Limestone, 80%, gray to brown (N6-5YR7/2), microcrystalline to very fine, dolomitic. Chert, 20%, gray (N7-9).
	SILURIAN SYSTEM
1246-1760	Salina Group
1246-1353	F Unit
1236-1258	Dolomite, 50%, brown (10YR6/2), lithographic, argillaceous (20%). Shale, 50%, gray (N4), bedded, 20% dolomite cement.
1258-1280	Dolomite, 100%, gray to brown (N4-5YR7/1), lithographic, argillaceous (40%). With a few white (N9) crystalline anhydrite fragments.
1280-1300	Lutite, 90%, gray to brown (N4-5YR7/1), homogeneous, dolomitic (40%), anhydritic (30%), argillaceous (30%). With a few gray (N4) shale and brown (5YR7/1) dolomite fragments. Anhydrite, 10%, white (N9), fine to coarsely crystalline. Appears as "oolites" in a lutite matrix.
1300-1312	Same as 1280-1300.
1312-1321	Lutite, 100%, gray to brown (N4-5YR7/1), same as 1280-1300.
1321-1231	Same as 1312-1321. With brown (5YR6/2) anhydrite crystal inclusions.
1331-1343	Lutite, 80%, brown (5YR7/1), same is 1280-1300. Anhydrite, 20%, white to brown (N9-10YR6/2), crystalline.
1343-1356	Lutite, 60%, gray to brown (N6-5YR6/1), same as 1280-1300. Anhydrite, 40%, white to brown (N9-10YR6/2), crystalline.
1353-1432	E Unit
1356-1379	Dolomite, 70%, gray to brown (N4-5YR6/1), lithographic, argillaceous (40%). Anhydrite, 30%, white (N9), crystalline.
1379-1393	Dolomite, 95%, same as 1356-1379. With brown (10YR6/2) anhydrite crystal inclusions. Anhydrite, 5%, white (N9), crystalline.
1393-1405	Same as 1379-1393.
1405-1417	Dolomite, 80%, brown (5YR6/1), lithographic, argillaceous (30%). Anhydrite, 20%, white to brown (N9-10YR7/2) crystalline.

Well C1-D6, Salina Group, E Unit (con.)

1417-1428	Same as 1405-1417.
1428-1438	Lutite, 100%, brown (10YR6/2), homogeneous, dolomitic (60%), argillaceous (30%), anhydritic (10%).
1432-1480	C Unit*
1438-1449	Dolomite, 90%, gray to brown (N6-5YR6/1), lithographic, argillaceous (40%). With a few gray (N4-5) shale fragments.
	Anhydrite, 10%, same as 1405-1417.
1449-1460	Dolomite, 50%, gray to brown (N5-5YR5/1), lithographic, argillaceous (40%).
	Shale, 50%, gray (N5-6), bedded, dolomitic (40%).
1460-1480	Shale, 80%, gray-green (5GY6/1), bedded, 20% dolomite cement. With a few pyrite crystal inclusions.
	Dolomite, 20%, same as 1449-1460.
1480-1518	B Unit
1480-1503	Shale, 50%, same as 1460-1480.
	Dolomite, 50%, same as 1449-1460.
1503-1518	Anhydrite, 50%, gray (N7), bedded, argillaceous (40%).
	Lutite, 45%, gray to brown (N5-5YR6/1), homogeneous, dolomitic (60%), argillaceous (40%).
	Shale, 5%, gray (N5), bedded, 20% dolomite cement.
1518-1760	Greenfield
1518-1530	Dolomite, 100%, gray to brown (N5-5YR6/1), lithographic, argillaceous (40%). With anhydrite fragments and inclusions.
1530-1543	Shale, 70%, gray (N5-6), bedded, dolomitic (40%).
	Dolomite, 30%, same as 1518-1530.
1543-1564	Shale, 50%, same as 1530-1543.
	Dolomite, 40%, brown (5YR5-6/1), lithographic to microcrystalline, argillaceous (20%).
	Anhydrite, 10%, white (N9), crystalline.
1564-1579	Dolomite, 100%, gray (N5-6), argillaceous (40%). With a few pyrite crystal inclusions and white (N9) crystalline anhydrite fragments.
1579-1591	Dolomite, 90%, same as 1564-1579.
	Anhydrite, 10%, white (N9), crystalline.
1591-1604	Dolomite, 90%, brown (5YR4-5/1), lithographic to microcrystalline, argillaceous (20%). With a few gray (N4) shale fragments.
	Anhydrite, 10%, white (N9), crystalline.
1604-1610	Dolomite, 100%, brown (5YR5/1-7/2), microcrystalline to very fine, argillaceous (20%). With a few white (N9) crystalline anhydrite fragments.
1610-1621	Dolomite, 100%, gray to brown (N5-5YR5/2), same as 1604-1610.
1621-1630	Dolomite, 100%, gray (N5-6), microcrystalline.
1630-1637	Dolomite, 100%, gray (N5-6), lithographic, argillaceous (20%). With a few gray (N4) shale fragments.
1637-1656	Same as 1630-1637.
1656-1669	Shale, 100%, gray (N5-6), dolomitic (40%).
1669-1683	Dolomite, 100%, gray-brown (5YR5/1), lithographic to microcrystalline, argillaceous (40%).
1683-1698	Same as 1669-1683.
1698-1710	Lutite, 100%, gray (N5-6), homogeneous, argillaceous (40%), dolomitic (30%), anhydritic (30%).
1710-1715	Dolomite, 100%, gray to brown (N5-5YR6/1), lithographic, argillaceous (30%).
1715-1735	Dolomite, 85%, brown (5YR6/1), lithographic to microcrystalline.
	Shale, 10%, gray (N4-5), bedded, 20% dolomite cement.
	Anhydrite, 5%, white (N9), crystalline, very fine.
1735-1751	Lutite, 100%, gray (N5-7), homogeneous, argillaceous (40%), anhydritic (40%), dolomitic (20%).
1760-1815	Lockport Group
1751-1763	Dolomite, 100%, brown (5YR7/2), lithographic to microcrystalline.
1763-1775	Dolomite, 100%, brown (5YR6-7/2), microcrystalline to very fine, sucrosic, intercrystalline porosity (1-5%).
1775-1785	Same as 1763-1775.
1785-1799	Same as 1763-1775.
1799-1811	Same as 1763-1775.
1815- ---	Clinton Group
1811-1825	Shale, 100%, gray (N4-5), bedded, dolomitic (30%).

*D Unit not represented

WELL C9

Ohio Geological Survey Sample 816, State Permit 12.

Trumbull County, Hartford Township, Lot 25, Dinger - No. 1 Blaney. Elevation: 1204 feet.

Depth, feet	Descriptions of well samples
	DEVONIAN SYSTEM
	Oriskany Sandstone
2277-2281	Sandstone, 95%, white (N10), quartz, fine, angular, well sorted, 10% calcareous cement.
	Shale, 5%, gray (N4), bedded, 20% calcareous cement.
	SILURIAN SYSTEM
3381-3538	Bass Islands Group
3381-3387	Limestone, 100%, gray to brown (N4-5YR4/1), lithographic, argillaceous (30%). With many sand grains.
3387-3397	Limestone, 100%, gray to brown (N7-5YR4/1), lithographic to microcrystalline, argillaceous (30%). With a few gray (N6-8) chert fragments.
3397-3408	Limestone, 90%, gray to brown (N7-5YR4/1), lithographic to microcrystalline, argillaceous (50%).
	Chert, 10%, gray-brown (5YR5-8/1).
3408-3413	Limestone, 80%, brown (5YR5/1), lithographic to microcrystalline, argillaceous (20%).
	Shale, 20%, gray (N4), bedded, calcareous (50%).
3413-3418	Limestone, 50%, brown (5YR7/1), lithographic, argillaceous (20%).
	Shale, 50%, gray (N4), bedded, 10% calcareous cement.
3418-3425	Shale, 80%, same as 3413-3418.
	Limestone, 20%, same as 3413-3418.
3425-3429	Shale, 90%, same as 3413-3418.
	Limestone, 10%, same as 3413-3418.
3429-3442	Limestone, 60%, same as 3413-3418.
	Shale, 40%, same as 3413-3418.
3442-3458	Shale, 60%, same as 3413-3418.
	Limestone, 40%, same as 3413-3418.
3458-3467	Limestone, 70%, same as 3413-3418.
	Shale, 30%, same as 3413-3418.
3467-3473	Limestone, 95%, same as 3413-3418.
	Shale, 5%, same as 3413-3418.
3473-3488	Limestone, 100%, brown (5YR7/1), lithographic. With a few gray (N4) shale fragments.
3488-3500	Limestone, 100%, brown (5YR6/1), same as 3476-3488.
3500-3505	Limestone, 80%, gray (N7), lithographic, dolomitic, argillaceous (30%).
	Limestone, 10%, brown (5YR7/1), lithographic to microcrystalline.
	Shale, 10%, gray (N4), bedded, 20% calcareous cement.
3505-3510	Dolomite, 90%, gray to brown (N7-5YR7/1), lithographic, calcareous. With a few quartz grain inclusions.
	Shale, 10%, gray (N4), same as 3500-3505.
3510-3515	Dolomite, 80%, brown (5YR5-6/1), lithographic to microcrystalline. With a few chert fragments.
	Shale, 20%, gray (N4), dolomitic (50%).
3515-3525	Dolomite, 100%, gray to brown (N4-5YR5/1), lithographic to microcrystalline, calcareous, argillaceous (40%).
3525-3537	Dolomite, 70%, gray-brown (5YR4-6/1), lithographic to microcrystalline. With a few brown (10YR4/2) anhydrite crystal inclusions.
	Anhydrite, 30%, gray to brown (N7-5YR8/1), bedded, argillaceous (20%).
3538-4426	Salina Group
3538-3668	G Unit
3537-3570	Lutite, 100%, gray to brown (N6-5YR4/1), homogeneous, anhydritic (40%), argillaceous (40%), dolomitic (20%).
3570-3590	Same as 3537-3570.
3590-3600	Lutite, 80%, same as 3537-3570.
	Shale, 20%, gray (N4), bedded, 10% dolomite cement.
3600-3610	Lutite, 90%, gray to brown (N6-5YR5/1), homogeneous, dolomitic (40%), argillaceous (40%), anhydritic (20%). With a few white (N9) crystalline anhydrite fragments.
	Shale, 10%, gray (N4), bedded, 10% dolomite cement.
3610-3622	Lutite, 90%, gray to brown (N6-5YR6/1), homogeneous, argillaceous (40%), anhydritic (30%), dolomitic (30%).
	Anhydrite, 10%, white (N10), very finely crystalline.
3622-3637	Lutite, 100%, same as 3610-3622.
3637-3652	Lutite, 100%, same as 3610-3622.
3652-3664	Lutite, 100%, same as 3610-3622.

Well C9, Salina Group (con.)

3668-3917	F Unit
3664-3677	Lutite, 90%, gray to brown (N5-5YR6/1), homogeneous, anhydritic (40%), argillaceous (40%), dolomitic (20%).
	Dolomite, 10%, brown (5YR5/1), lithographic, argillaceous (20%).
3677-3687	Lutite, 100%, same as 3664-3677.
3687-3700	Lutite, 100%, same as 3664-3677.
3700-3711	Lutite, 95%, gray to brown (N6-5YR5/1), homogeneous, dolomitic (40%), argillaceous (30%), anhydritic (30%).
	Anhydrite, 5%, white (N10), very finely crystalline.
3711-3720	Lutite, 40%, brown (10YR7/2), homogeneous, argillaceous (40%), dolomitic (40%), anhydritic (20%).
	Shale, 30%, gray (N4), bedded, 10% dolomite cement. With a few pyrite crystal inclusions.
	Anhydrite, 30%, white (N10), very finely crystalline.
3720-3738	Shale, 100%, brown (5YR7/1), dolomitic (50%).
3738-3757	Dolomite, 100%, brown (5YR7/1), lithographic, argillaceous (40%). With pinpoint vugs and a few black (N2-3) shale fragments.
3757-3776	Dolomite, 85%, same as 3738-3757.
	Anhydrite, 15%, white (N10), very finely crystalline.
3776-3784	Lutite, 95%, brown (10YR6/2), homogeneous, dolomitic (40%), argillaceous (30%), anhydritic (30%). With a few black (N2-3) shale fragments.
	Anhydrite, 5%, white (N10), very finely crystalline.
3800-3810	Lutite, 95%, brown (10YR6/2), same as 3776-3784.
	Anhydrite, 5%, gray (N7), crystalline, argillaceous (20%).
3810-3820	Lutite, 100%, same as 3800-3810.
3820-3829	Same as 3810-3820.
3829-3838	Lutite, 70%, brown (5YR6/1), same as 3800-3810. With a few pyrite crystal inclusions.
	Anhydrite, 30%, white (N9-5YR8/1), very finely crystalline.
3838-3852	Lutite, 80%, same as 3829-3838.
	Anhydrite, 20%, same as 3829-3838.
3852-3872	Lutite, 60%, same as 3829-3838. With a few anhydrite fragments.
	Shale, 40%, gray (N4), bedded, 20% dolomite cement.
3872-3891	Same as 3852-3872.
3891-3914	Lutite, 100%, brown (5YR6/1), homogeneous, argillaceous (40%), dolomitic (40%), anhydritic (20%). With a few anhydrite and gray (N4) shale fragments.
3917-4071	E Unit
3914-3928	Shale, 60%, gray to green (N6-5G6/1), dolomitic (50%). With a few gray (N4) shale fragments.
	Lutite, 20%, brown (5YR6/1), homogeneous, argillaceous (60%), dolomitic (20%), anhydritic (20%).
	Anhydrite, 20%, white (N9-5YR8/1), very finely crystalline.
3928-3936	Shale, 80%, same as 3914-3928.
	Anhydrite, 20%, same as 3914-3928.
3936-3946	Lutite, 100%, gray to brown (N5-5YR6/1), homogeneous, argillaceous (40%), dolomitic (30%), anhydritic (30%).
3946-3958	Same as 3936-3946.
3958-3972	Dolomite, 100%, brown (5YR5-6/1), lithographic, anhydritic (30%), argillaceous (20%). With a few pinpoint vugs.
3972-3792	Same as 3958-3972.
3992-4012	Shale, 80%, brown (5YR7/1), dolomitic (50%).
	Dolomite, 20%, brown (5YR5-6/1), lithographic, argillaceous (20%). With a few pinpoint vugs and white (N9) anhydrite fragments.
4012-4026	Shale, 100%, brown (5YR7/1), dolomitic (50%). With a few white (N9) anhydrite fragments.
4026-4038	Dolomite, 50%, brown (5YR5-6/1), lithographic, argillaceous (40%).
	Shale, 40%, same as 4012-4026.
	Anhydrite, 10%, white (N9), very finely crystalline.
4038-4048	Anhydrite, 60%, gray to brown (N6-5YR6/1), bedded, argillaceous (20%), dolomitic (10%).
	Shale, 40%, brown (5YR7/1), bedded, dolomitic (30%).
4048-4058	Anhydrite, 50%, same as 4038-4048.
	Shale, 50%, same as 4038-4048.
4058-4073	Same as 4048-4058.
4071-4110	D Unit
4073-4091	Shale, 70%, brown (5YR6/1), dolomitic (50%).
	Anhydrite, 30%, same as 4038-4058.
4091-4112	Shale, 70%, brown (5YR6/1), bedded, dolomitic (30%).
	Anhydrite, 30%, same as 4038-4058.
4110-4180	C Unit
4112-4122	Same as 4091-4112. With a few gray (N4) shale fragments and sub-rounded quartz grains.
4122-4132	Shale, 100%, same as 4091-4112. With a few anhydrite fragments and pyrite crystal inclusions.
4132-4142	Shale, 100%, gray to green (N6-5G6/1), dolomitic (40%). With a few anhydrite fragments and quartz grains.
4142-4152	Shale, 80%, same as 4132-4142.
	Anhydrite, 20%, white (N10), crystalline.
4152-4162	Shale, 60%, green (5G7/1), dolomitic (50%). With a few anhydrite fragments.
	Shale, 30%, gray to brown (N6-5YR6/1), dolomitic (30%).
	Shale, 10%, black (N3-4), bedded, 20% dolomite cement.
4162-4172	Shale, 60%, gray to brown (N6-5YR6/1), same as 4152-4162.
	Shale, 20%, green (5G7/1), same as 4152-4162.
	Shale, 20%, black (N3-4), same as 4152-4162.
4172-4190	Shale, 35%, gray to brown (N6-5YR6/1), same as 4152-4162.
	Shale, 30%, black (N3-4), same as 4152-4162.
	Shale, 30%, green (5G7/1), dolomitic (30%).
	Anhydrite, 5%, white (N9), crystalline.
4180-4315	B Unit
4190-4200	Same as 4172-4190.
4200-4212	Same as 4172-4190.
4212-4220	Shale, 90%, brown (5YR6-7/1), dolomitic (50%), some gray, green and black shale fragments.
	Anhydrite, 10%, white (N9-5YR8/1), crystalline.
4220-4227	Shale, 60%, green (5G7/1), same as 4172-4190.
	Shale, 25%, brown (5YR6-7/1), same as 4172-4190.
	Shale, 5%, black (N3-4), same as 4172-4190.
	Anhydrite, 10%, white, same as 4212-4220.
4227-4231	Shale, 70%, green (5GY7/1), dolomitic (30%).
	Shale, 30%, brown (5YR6-7/1), dolomitic (30%). With a few black (N3-4) shale and white (N9) anhydrite fragments.
4231-4240	Shale, 45%, green, same as 4227-31.
	Shale, 45%, brown, same as 4227-31.
	Anhydrite, 10%, white (N9), very finely crystalline.
4240-4250	Same as 4231-4240.
4250-4260	Same as 4231-4240.
4262-4275	Lutite, 100%, brown (5YR6/1), homogeneous, argillaceous (50%), anhydritic (30%), dolomitic (20%).
4275-4292	Lutite, 100%, gray to brown (N6-5YR6/1), homogeneous, argillaceous (60%), dolomitic (20%), anhydritic (20%).
4292-4303	Same as 4275-4292.
4303-4315	Shale, 70%, green (5G5/1), bedded, 20% dolomite cement. With a few white (N9) anhydrite fragments.
	Shale, 30%, brown (10YR6/1), dolomitic (40%).
4315-4426	Greenfield
4315-4330	Shale, 60%, brown (5YR6/1), dolomitic (20%).
	Anhydrite, 40%, brown (5YR5/1), bedded, dolomitic (30%).
4330-4345	Dolomite, 80%, brown (5YR4/1), lithographic, argillaceous (20%).
	Anhydrite, 20%, gray to brown (N6-5YR5/1), bedded.
4345-4357	Dolomite, 100%, same as 4330-4345.
4357-4377	Dolomite, 100%, brown (5YR3/1), lithographic to microcrystalline, argillaceous (20%). With a few gray (N4-5) shale and white (N9) anhydrite fragments.
4377-4390	Same as 4357-4377.
4390-4399	Anhydrite, 70%, gray to brown (N5-5YR8/1), very finely crystalline.
	Dolomite, 15%, brown, same as 4357-4377.
	Shale, 15%, gray (N4), bedded, 20% dolomite cement.
4399-4409	Anhydrite, 40%, brown (5YR8/1), very finely crystalline.
	Dolomite, 30%, brown (5YR5/1), same as 4357-4377.
	Shale, 30%, gray (N4-6), bedded, 20% dolomite cement.
4409-4420	Anhydrite, 70%, same as 4399-4409.
	Shale, 30%, same as 4399-4409.
4420-4426	Same as 4409-4420.
4426-4625	Lockport Group
4426-4436	Dolomite, 100%, brown (5YR4-6/1), lithographic to microcrystalline, argillaceous (10%). With a few white (N9) anhydrite and gray (N4) shale fragments.
4426-4445	Dolomite, 100%, gray to brown (N4-5YR7/1), same as 4426-4436. With no anhydrite fragments.
4445-4453	Same as 4436-4445.
4453-4462	Same as 4436-4445.
4462-4466	Same as 4436-4445.
4466-4475	Same as 4436-4445.
4475-4484	Dolomite, 100%, brown (5YR4/1), same as 4436-4445. With a few gypsum crystals.
4484-4487	Dolomite, 100%, gray to brown (N6-5YR6/1), lithographic, argillaceous (10%). With a few gray (N4) shale fragments.
4487-4498	Same as 4484-4487.
4498-4506	Same as 4484-4487.
4506-4516	Dolomite, 100%, brown (5YR4-6/1), lithographic to microcrystalline.
4516-4528	Dolomite, 100%, brown (10YR7/2), microcrystalline to very fine, intercrystalline porosity (1-5%).
4528-4535	Same as 4516-4528. With a few gypsum crystals.
4535-4550	Same as 4516-4528.
4550-4555	Same as 4516-4528, very fine to finely crystalline, intercrystalline porosity (5-10%).
4555-4566	Same as 4516-4528.
4566-4572	Same as 4550-4555.
4572-4582	Dolomite, 100%, brown (10YR5/2), very fine to finely crystalline, intercrystalline porosity (1-5%). Cuttings resemble sand.
4582-4586	Shale, 60%, gray (N4), bedded, 20% dolomite cement.
	Dolomite, 40%, same as 4572-4582.
4586-4592	Dolomite, 70%, same as 4572-4582.
	Shale, 30%, same as 4582-4586.
4592-4600	Dolomite, 85%, same as 4572-4582.
	Shale, 10%, same as 4582-4586.
	Shale, 5%, blue (5B7/1), bedded.

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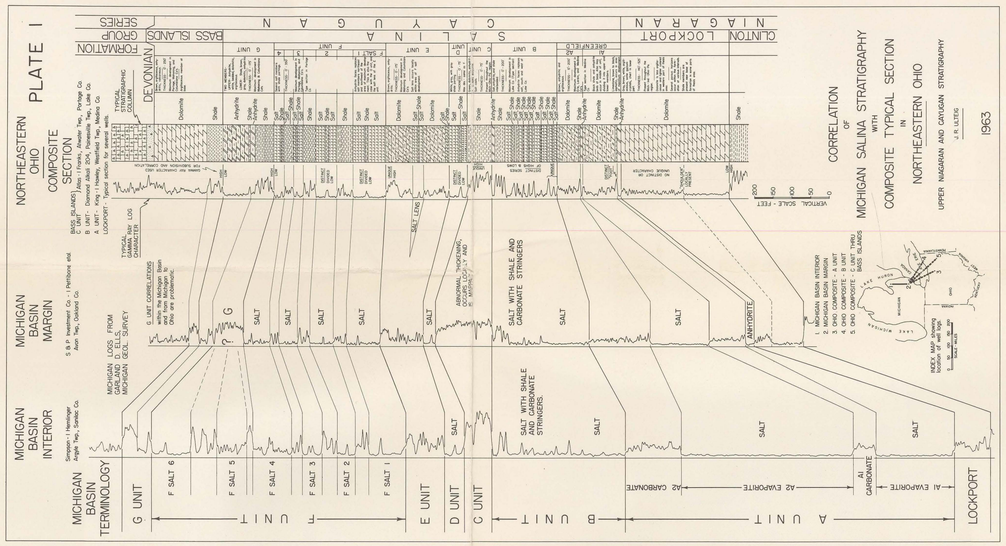

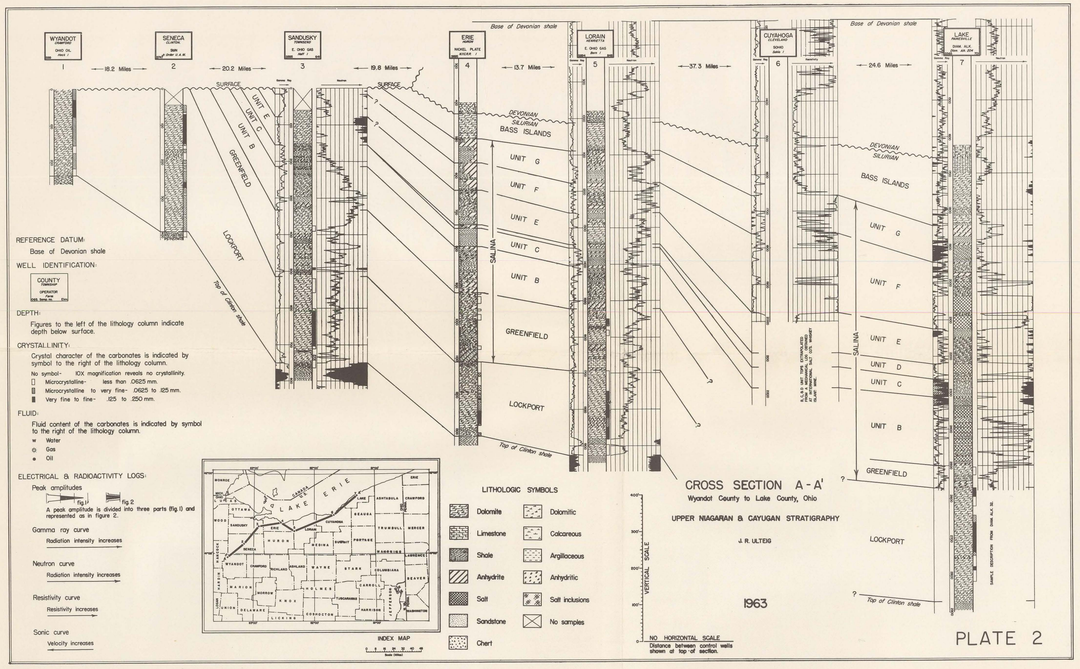

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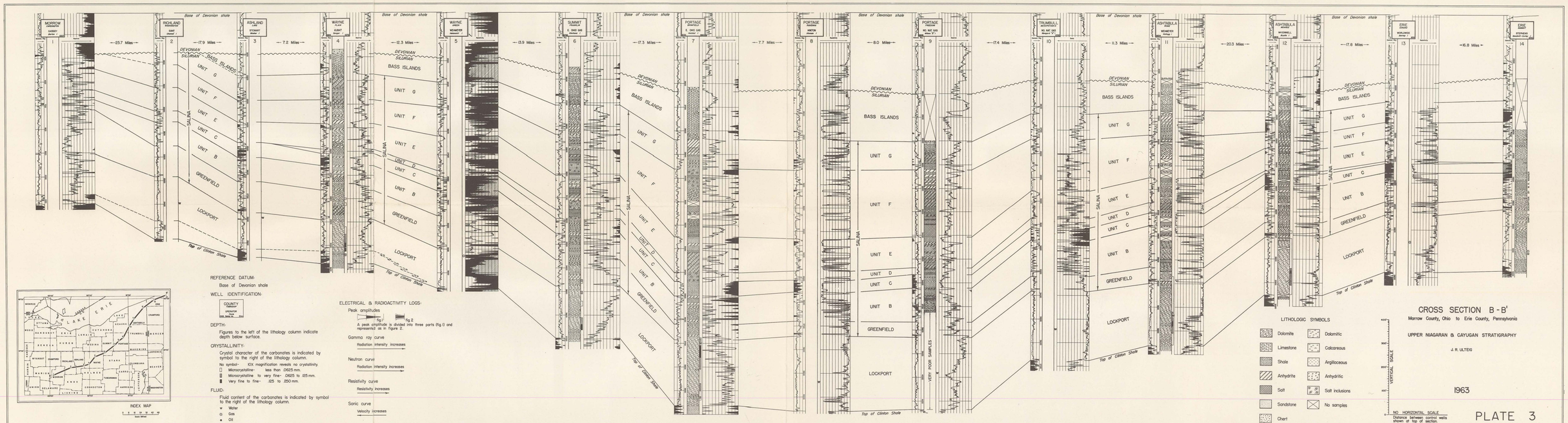
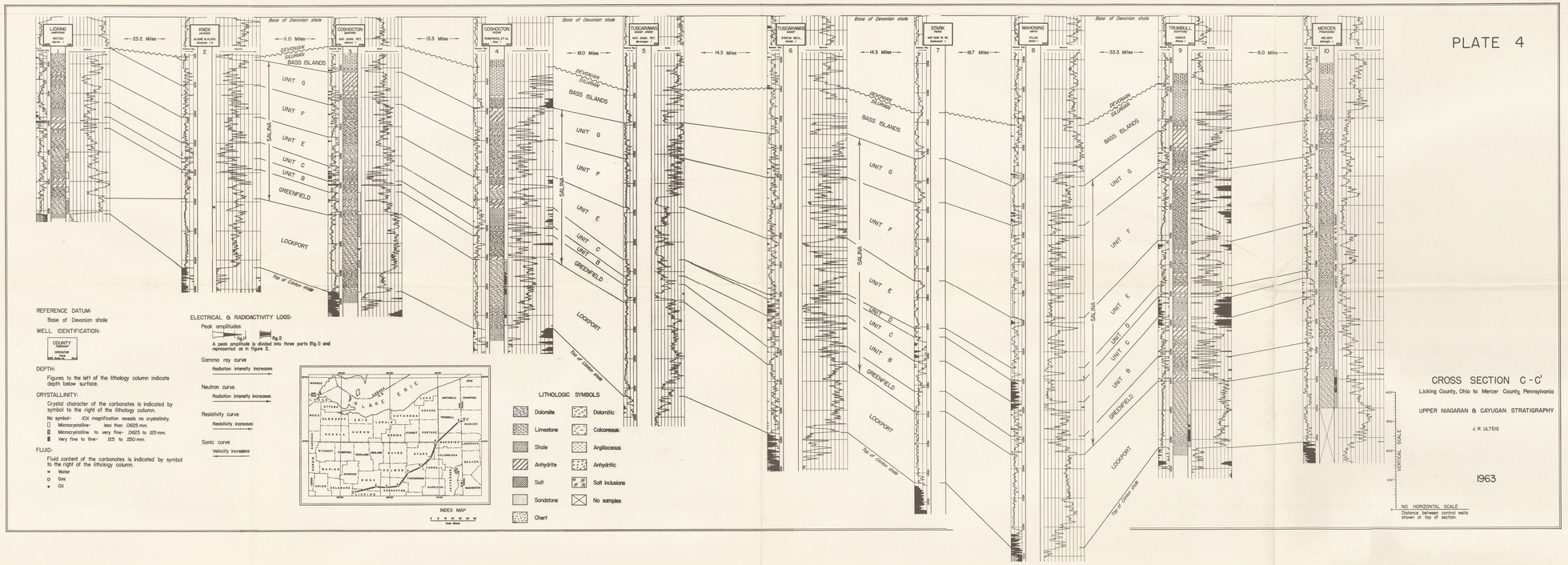
UPPER NIAGARAN AND CAYUGAN STRATIGRAPHY OF NORTHEASTERN OHIO AND ADJACENT AREAS

Report of Investigations No. 51





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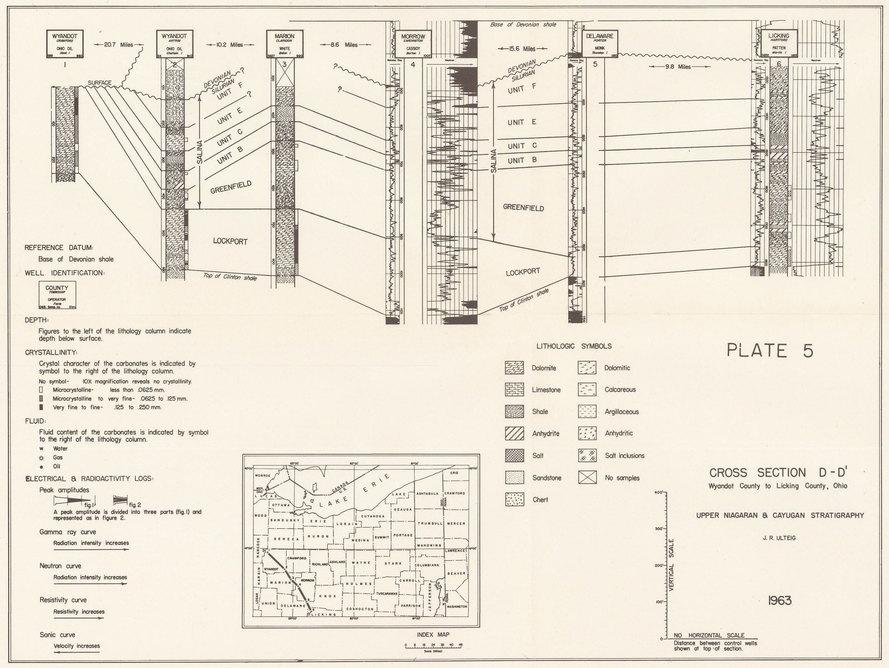
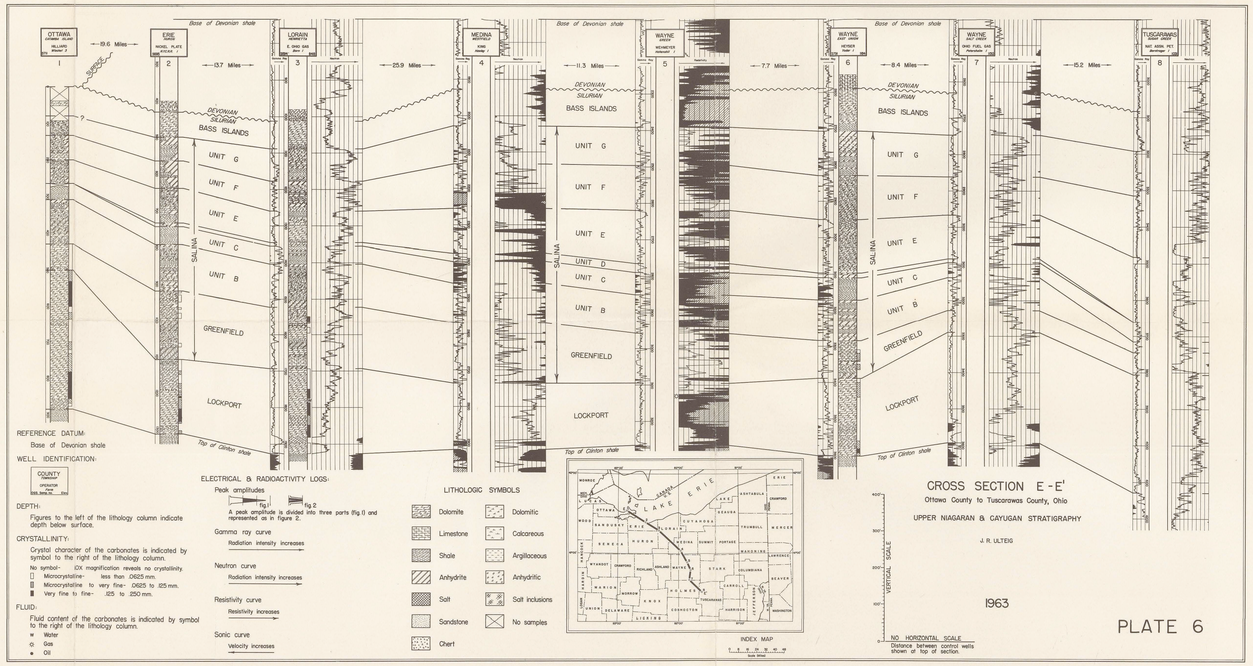




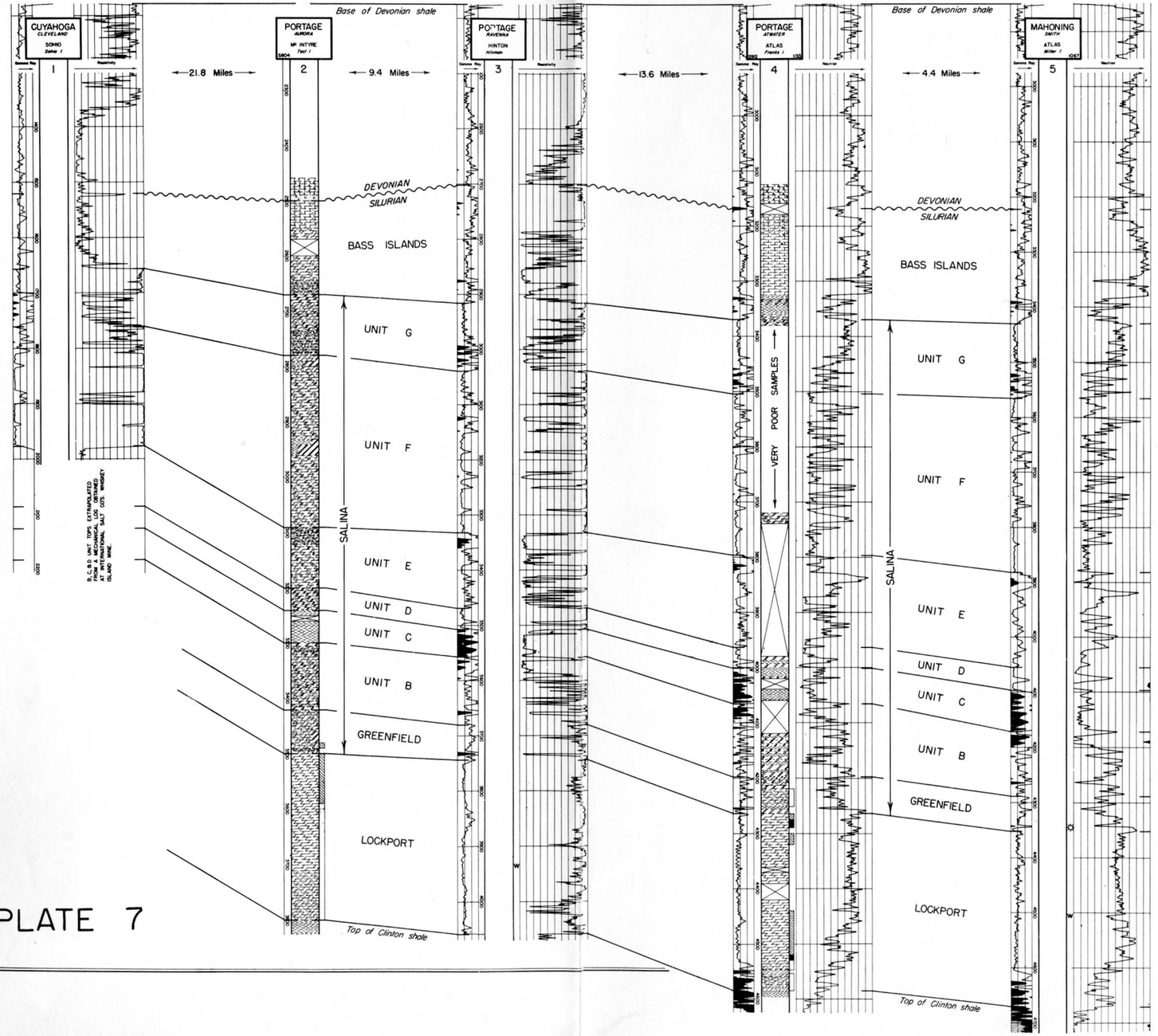


PLATE 7

REFERENCE DATUM:

Base of Devonian shale

WELL IDENTIFICATION:

COUNTY
TOWNSHIP
OPERATOR
Farm
OWO. Samp. no. Elev.

DEPTH:

Figures to the left of the lithology column indicate depth below surface.

CRYSTALLINITY:

Crystal character of the carbonates is indicated by symbol to the right of the lithology column.

No symbol- 10X magnification reveals no crystallinity.
Microcrystalline- less than .0625 mm.
Microcrystalline to very fine- .0625 to .125 mm.
Very fine to fine- .125 to .250 mm.

FLUID:

Fluid content of the carbonates is indicated by symbol to the right of the lithology column.

w Water
Gas
Oil

ELECTRICAL & RADIOACTIVITY LOGS:

Peak amplitudes

fig.1 fig.2

A peak amplitude is divided into three parts (fig.1) and represented as in figure 2.

Gamma ray curve

Radiation intensity increases

Neutron curve

Radiation intensity increases

Resistivity curve

Resistivity increases

Sonic curve

Velocity increases

LITHOLOGIC SYMBOLS

Dolomite	Dolomitic
Limestone	Calcareous
Shale	Argillaceous
Anhydrite	Anhydritic
Salt	Salt inclusions
Sandstone	No samples
Chert	

CROSS SECTION F - F'

Cuyahoga County to Mahoning County, Ohio

UPPER NIAGARAN & CAYUGAN STRATIGRAPHY

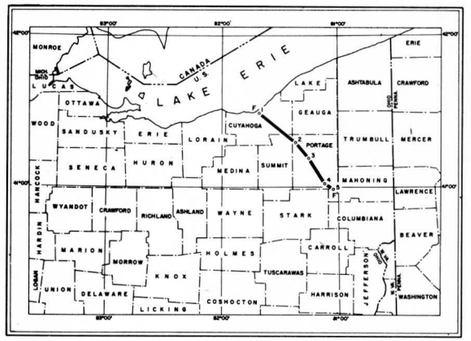
J. R. ULTEIG

1963

VERTICAL SCALE 400' 300' 200' 100' 0

NO HORIZONTAL SCALE

Distance between control wells shown at top of section.



INDEX MAP

Scale (Miles)

Ohio Division of Geological Survey

UPPER NIAGARAN AND CAYUGAN STRATIGRAPHY OF NORTHEASTERN OHIO AND ADJACENT AREAS

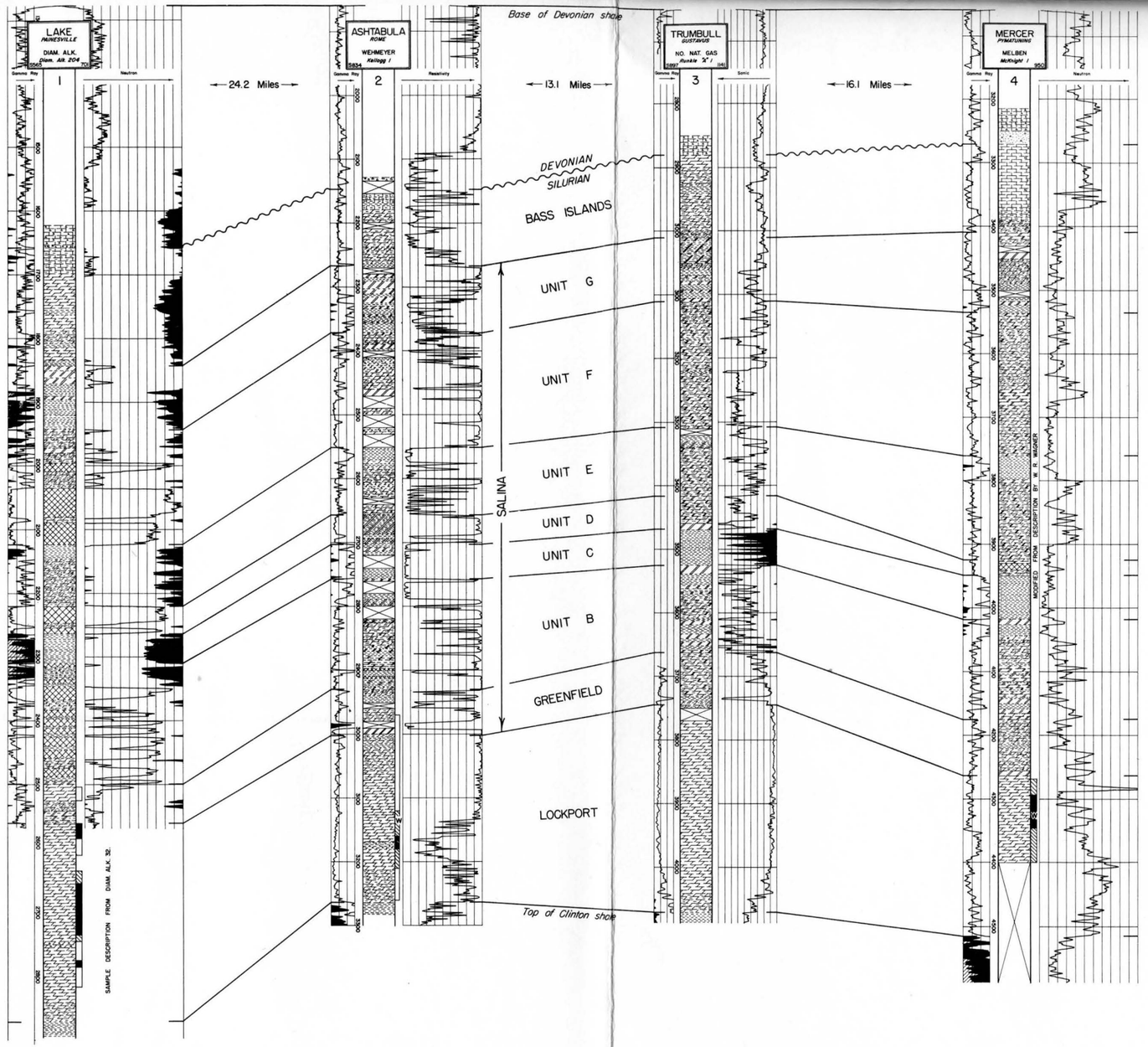


PLATE 8

REFERENCE DATUM:

Base of Devonian shale

WELL IDENTIFICATION:

COUNTY
TOWNSHIP
OPERATOR
Farm
OGS Samp. no. Elev.

DEPTH:

Figures to the left of the lithology column indicate depth below surface.

CRYSTALLINITY:

Crystal character of the carbonates is indicated by symbol to the right of the lithology column.

No symbol- 10X magnification reveals no crystallinity.
Microcrystalline- less than .0625 mm.
Microcrystalline to very fine- .0625 to .125 mm.
Very fine to fine- .125 to .250 mm.

FLUID:

Fluid content of the carbonates is indicated by symbol to the right of the lithology column.

w Water
Gas
• Oil

ELECTRICAL & RADIOACTIVITY LOGS:

Peak amplitudes

fig.1 fig.2

A peak amplitude is divided into three parts (fig.1) and represented as in figure 2.

Gamma ray curve

Radiation intensity increases

Neutron curve

Radiation intensity increases

Resistivity curve

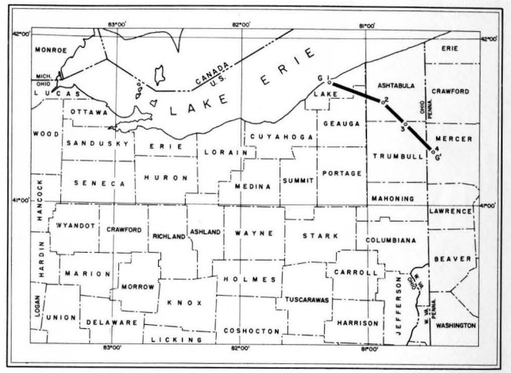
Resistivity increases

Sonic curve

Velocity increases

LITHOLOGIC SYMBOLS

Dolomite	Dolomitic
Limestone	Calcareous
Shale	Argillaceous
Anhydrite	Anhydritic
Salt	Salt inclusions
Sandstone	No samples
Chert	



INDEX MAP

0 8 16 24 32 40 48
Scale (Miles)

CROSS SECTION G - G'

Lake County, Ohio to Mercer County, Pennsylvania

UPPER NIAGARAN & CAYUGAN STRATIGRAPHY

J. R. ULTEIG

1963

VERTICAL SCALE
400'
300'
200'
100'
0

NO HORIZONTAL SCALE
Distance between control wells shown at top of section.